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DEVELOPMENT OF A SIMULATION MODEL FOR A POTASH COMPACTION CIRCUIT

FINAL REPORT

BY

KILBORN (SASKATCHEWAN) LTD.

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1.0 BACKGROUND

During the 1987 financial year, Kilborn was awarded a contract under the Unsolicited Proposals Program to study the compaction process with the goal of developing models for the unit operations that are used in the milling of potash. The contract provided Kilborn with up to $25,000 of funding as a contribution toward the development of these models. Kilborn had previously done work on its own in this area in 1985 and 1986. During this period a need for such research and development was identified through attempts to improve the design element of the engineering of compaction circuits.

Work on this project was delayed for a number of reasons including the need to redefine objectives in the light of the availability of data and personnel from operating mines. In return for an extension to the final delivery date of results, Kilborn agreed to limit the maximum CANMET contribution to approximately $20,000 which was the total expended at the time of the request for extension. Kilborn also agreed to continue the work at Kilborn's cost.

As is most often the case with research and development, success leads to a continuation of efforts rather than a well defined completion. Kilborn is sufficiently satisfied with the results of this work as to be committed to its furtherance. The future

objectives of Kilborn work on compaction will be to continue this work in cooperation with its potash clients with the goal of developing improved compactor operation through simulation models. Kilborn is also committed to the entry of SPOC compatible models into the SPOC library as they become calibrated and documented. Kilborn will endeavour to update the models that are presented in this report.

1.1 INTRODUCTION TO POTASH COMPACTION

Granular potash may be obtained through the use of compactors. These units consist of roll presses which produce a flake by compacting hot undersized material from the screening section of the potash process. The hot flake is broken by impact crushers and then screened so that approximately 30 percent of the screened product is within the size range +1500 microns to -3200 microns. This product is desirable because it is less subject to dusting loss in transit and during application. Also it provides a more gradual release of the KCl plant nutrient in the soil.

Compaction is an economically important part of the overall potash refining process. The premium for granular product varies upwards from $10 per ton of product. During periods of poor sales, granular product has often been in demand while other products were overstocked.

The heart of the compaction flowsheet is shown conceptually in Figure 1.0. Normally, feed to the compaction process is from two sources, the standard and special standard bins. Either of these products may be white or red. White products emanate from the recrystallization process and the red products result from flotation. The red coloration is due to trace quantities of hematite in the potash ore.

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Material from the above storage bins is fed to a compaction feed bin which feeds the roll presses of the compactor by gravity or through force feeders. The compaction rolls are either smooth or corrugated. However, time has proven that corrugated rolls produce greater productivity and produce flake more efficiently. Flake produced by the compactors is moved via screw conveyors to the impact crusher. Generally, there is one impact crusher for every two compactors. The crushed material from the impact crusher is fed by a system of screw conveyors and bucket elevators to a set of vibrating screens which recycle the undersize to the compactors and the oversize to the impactors. The intermediate size is quenched in a dryer and polished in a subsequent set of screens with further recycling of oversize and undersize to the main compaction circuit. The intermediate product from the polishing screens is the final granular product.

The compaction process is a high cost portion of the overall process. During the economic lows in the market, production costs may be a substantial portion of the price, yet granular may be the best selling product. During periods of high demand the premium for granular product tends to be proportionately greater than the improvement in general product pricing, making it advantageous to produce as much granular product as possible.

Potash compaction is one of the most poorly understood parts of the potash flowsheet. Progress in the understanding of the

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process has been slow. The major operational problem has been low productivity and inconsistent operation. Early attempts at modelling this process dealt with internal effects such as the influence of feed pressure, roll pressure, temperature and roll torque on the quality and consistency of the compactor flake. The work of Johanson dealt with these internal effects. Subsequent to this Johanson and Banks published a paper in 1975 which addressed the problem of achieving higher production rates for existing roll presses. This work has led to internal design modifications for roll presses.

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1.2 SUMMARY OF RESULTS

This report is the result of a study of the potash compaction process through the use of phenomenological tools. The compactor, screen, and impactor units have been modelled individually with the goal of developing prediction methods that will permit the use of circuit simulators such as SIMBAL. This approach lumps a number of unit processes into a single overall unit in order to make the simulation process more tractable.

(1) The work has tested the use of modern mass balancing techniques using coherent mass balancing. The results demonstrate the feasibility of determining circulating loads in a potash compaction circuit, in the absence of accurate mass flow measurement, through the combined use of sampled particle size analysis and coherent mass balancing systems such as BILMAT from the SPOC library.

(2) A model has been developed which describes the compactor and impactors in terms of matrices for selection, breakage and upgrading of the particle size distribution. The study of these matrices has provided insight into the performance of the compactor and impactor units that is not easily obtained through a study of the particle size distributions alone. The study has shown that regression procedures previously developed for ball mills can be

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applied equally well to potash impactors.

(3) A technique for predicting the shape parameters of particle size distributions in a compactor circuit has been developed. This includes predicting the "difficult and important size distribution" of the compactor flake, which is the result of compacting almost powdery potash material. The prediction method results from the application of "Chaos Theory" to understanding physical processes through the use of classical statistical mechanics.

Summarizing, the study results provide two alternative models for the compactor unit, an impactor model, and confirmation of the validity of the Karra model in the SPOC library. At this time, these models are mathematical in form, with SPOC models serving as their prototypes for implementation in a simulator.

The study has produced a spreadsheet simulator that has been used to test model validity.

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1.3 GENERAL METHODOLOGY

In order to simulate a potash compaction circuit it is necessary to develop a combined unit model for the compactor/impactor combination. Such a model provides a means of predicting the mass flow rate and particle size distribution of the material leaving the impactor as a function of the mass flow rates and size distributions of the feed to the compactor and the material that bypasses the compactor to the impactor. It is also a function of the internal parameters of the compactor and impactor such as roll pressure, rpm, etc.

The key process measurements in compaction are flows and size analyses. Flow measurement is achievable at points where belt conveyors are utilized. In the compaction circuits that were studied there are only a few such points at the feed and final product ends of the circuit. Key intermediate points involve screw conveyors and bucket elevators. Currently, affordable mass flow measurement technology for these streams is not available.

On-stream particle size analysis is not technically feasible at the present time for the compaction circuit size range of particles. Successful techniques for on-stream particle size analysis involve the slurrying of particulate samples followed by continuous particle size analysis. Current technology limits the maximum particle size to 1000 microns.

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Improvements in potash compaction can be achieved through the following traditional steps:

(1) Samples are obtained around the circuit at a sufficient number of points. This information is taken in conjunction with flow measurements and internal compactor measurements such as flake thickness, roll pressure, etc.

(2) An attempt is made to balance the size fractions around the circuit. Particular attention is paid to the circulating load which bypasses the compactor units and the circulating load that passes through the compactors.

(3) Each screen, impactor and compactor is studied on a stand alone basis combining the results of the mass balance with all other information which is at hand for that unit, much of which is semi quantitative. The performance of the impact crusher is usually the main concern.

The determination of circulating loads and the identification of the performance of the impactor has been unsatisfactory.

Consequently, there is interest in the development of procedures and/or models of the compaction circuit that will assist in these determinations.

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The starting point for the study was the SPOC library of programs which contains four programs that were found to be applicable to the compaction process with little modification. These were the following programs:

. BILMAT - a computer program for material balance adjustment. Authored by D.Houdin and F. Flament and edited by D. Laguitton with contributions from R. Poirier, J. Wilson and M.D. Everell.

. KSCRN - a computer program to simulate an inclined vibrating screen based upon a model due to Karra. When used in sequence for the upper and lower decks, it was found to be applicable to the double-deck screening units that are used in the compaction process. KSCRN was authored by B. Flintoff.

. FINDBS - An identification program for determining the breakage and selection function of a ball mill. FINDBS was authored by V.K. Gupta, D. Houdouin and R. Spring.

. HCAL - An identification program for determining the partition function of a cyclone. HCAL was authored by B. Flintoff.

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A study of these programs involved a review of the documentation, which was found to be quite adequate, the generation of the programs and the running of the supplied test problems. Some problems were encountered with an early version of the BILMAT program, owing to the large number of nodes and streams anticipated in a full compaction circuit, but these were corrected through a later release. Otherwise, all the SPOC components used in the study were found to consist of clean well-documented FORTRAN programs written to an excellent standard. They are efficient and accurate to within the limits stated in the documentation.

The Potash Corporation of Saskatchewan (PCS) has provided data from circuit tests that were conducted at their Cory and Lanigan Divisions. In addition, they have helped to identify problems with these circuits that might be solved through the development of models. The analytical procedures that are currently being used have been explained by reference to the tests themselves.

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Several objectives for this study were identified with the help of the plant operators at Cominco, PCS and other potash companies:

. the identification of circulating loads through better mass balancing techniques.

. improved vibrating screen balancing methods particularly for double-decked screens.

. identification of screening parameters relating to partition functions in order to reduce the sampling requirements in future plant testing.

. determination of the nature of the selection and breakage functions in potash impactors.

. prediction of compactor flake characteristics in terms of particle size distributions.

. development of guidelines for the design of sampling experiments in compactor circuits.

. development of a conceptual framework for the application of expert systems technology to compactor operation.

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In an attempt to priorize these objectives it was established that the mass balancing was the highest and most immediate priority. This priority stems from the fact that flow measurement on key process streams is beyond the current limits of instrument technology or is not affordable. It was felt that circulating load definition would provide a means of establishing a reasonable balance around the impactors which in turn would provide a means of understanding the impactor's selection and breakage characteristics.

The next most important priority relates to the impactors. It was stressed that the essential quality of good flake is that it breaks in the impactor in such a way as to provide a high yield of granular material. Thus, the problem is the impaction of compactor flake just as much as the compaction of fines.

The remaining priorities relate to the compactor unit model and the development of a circuit simulator.

2.0 COMPACTOR PRINCIPLES

2.1 The Compaction Network

The essential part of a compactor circuit is illustrated by the network shown in Figure 1.0. In this representation the primary screening device might be the upper deck of a double-decked vibrating screen and the secondary screen might be the lower deck. In the PCS Cory tests, the primary and secondary screens are two positions of 4 X 5 Tyler screens which are arranged in series overflow. This screening arrangement is effectively a single screen with two different screen apertures.

The screening device releases three products:

. Undersize or dust which cycles back to the compactor.

. Oversize which bypasses the compactor to the impactor.

. Material in a size range acceptable for processing in the polishing circuit. Reject material from the polishing circuit contributes to the feed stream as shown in Figure 1.0.

In the PCS Cory test four screens were lumped together as one unit.

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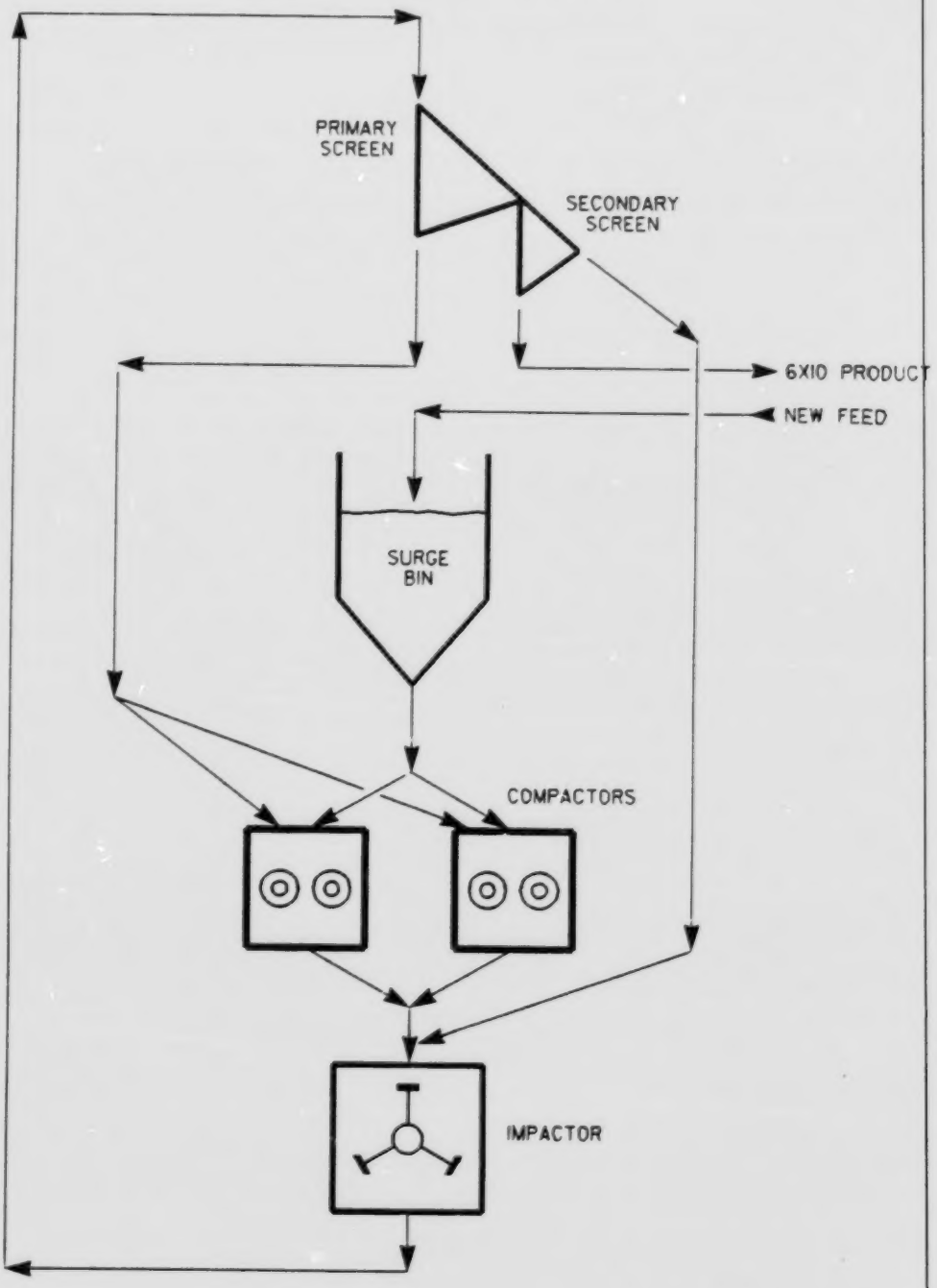
FIGURE 1.0

COMPACTOR CIRCUIT



2.2 Flake Production

Compactor flake production is determined from the following formula:

$$PR = a\ k\ \pi\ D\ w\ g\ r\ d \quad \text{.....(1)}$$

where

PR : the production rate in tonnes per hour.

w : the width of the roll press.

D : the diameter of the rolls.

g : the gap between the rolls (flake thickness).

r : the rotation rate in rpm.

d : the bulk density of the compacted flake.

k : a conversion factor to consistent units.

a : a correction factor for edge effects.

In the case of the PCS Cory test the compactor units were Allis Chalmers 24 X 24 compactors. These units are each capable of producing up to 60,000 pounds per hour of flake based upon their rated torque and rpm. At rated roll pressure, these presses will achieve flake densities nearly equal to the normal density of crystalline potash (sg = 1.98).

Equation (1) will predict compactor production to within plus or minus 5 percent. The major uncertainties are the bulk density and the edge correction. Operating experience with specific units must be relied upon to determine these effects.

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2.3 Compressive Pressure and Flake Strength

Flake formation between the roll presses of a compactor is mainly confined to an angle α_1 called the nip angle. This is the angle, in advance of the centreline joining the two rolls centres, at which the rolls no longer slip against the feed material. Pressure builds to a maximum at the centreline in the nip region and then declines until release occurs at an angle β_1 beyond the centreline. Maximum compressive pressure depends upon roll pressure, rpm, feed pressure and temperature. It is a determining factor in achieving adequate flake in terms of the particle size distribution. There is a limitation on the maximum compressive pressure as a function of roll rpm. For a typical potash powder plus granules, this relationship is of the form:

$$\sigma = \sigma_o \exp(-k\ r) + \sigma_1 \qquad (2)$$

where σ_o, k, σ_1 are parameters that can be determined experimentally for a particular compactor unit.

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2.4 Particle Size Distribution

Compactor flake, as it leaves the roll presses, is subject to a certain amount of quasi-spontaneous breakage. The flake breaker and the screw conveyors that transport flake cause considerable breakage. Therefore, the flake as it leaves the roll presses will not provide a representative sample in terms of size analysis. A more appropriate point is just prior to where the material is input to the impactor and after the flake breaker if such a device is employed.

A worthwhile goal would be to develop prediction methods for the flake particle size distribution based upon internal compactor operating parameters and the size distribution parameters of the feed distribution. This will be essential to enable the ultimate simulation of compactor circuits.

A review of the literature only produced relationships between internal compactor variables and compressive pressure. This is of little value for particle size prediction since compressive pressure prediction does not lead directly to product particle size prediction. Nevertheless, compressive pressure defines a region for acceptable flake production. More specifically, there exists an operating region between compressive pressure versus pressing time curves that produces acceptable flake. In practice, these limits are fairly well known for existing units.

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This study has revealed some remarkable features of the flake particle size distribution which leads to a means of predicting flake particle size distribution.

Figure 2.2 shows a plot of key particle size distributions for samples taken around one of the PCS Cory compactor units. These plots show the cumulative particle size retained plotted on a scale of Weibull probability vs common logarithm. The abscissa is the Tyler mesh size and the ordinate is the Weibull probability representing the cumulative percent retained.

The most remarkable feature is the straight-line segmentation and low scatter displayed by the plot. The study hypothesis for this report is that this feature is characteristic of all potash particle size analyses for circuits that employ impact crushers. This hypothesis was tested for all the particle size distributions used in the study from both the Lanigan and Cory circuits.

The second remarkable feature is the slope of the straight line segments. From a study of all the flake particle size distributions, it was found that the coarse particle size segments were parallel to the fine particle size segments to within the accuracy of plotting. This would define a predominant shape factor for the flake particle size distribution. The key

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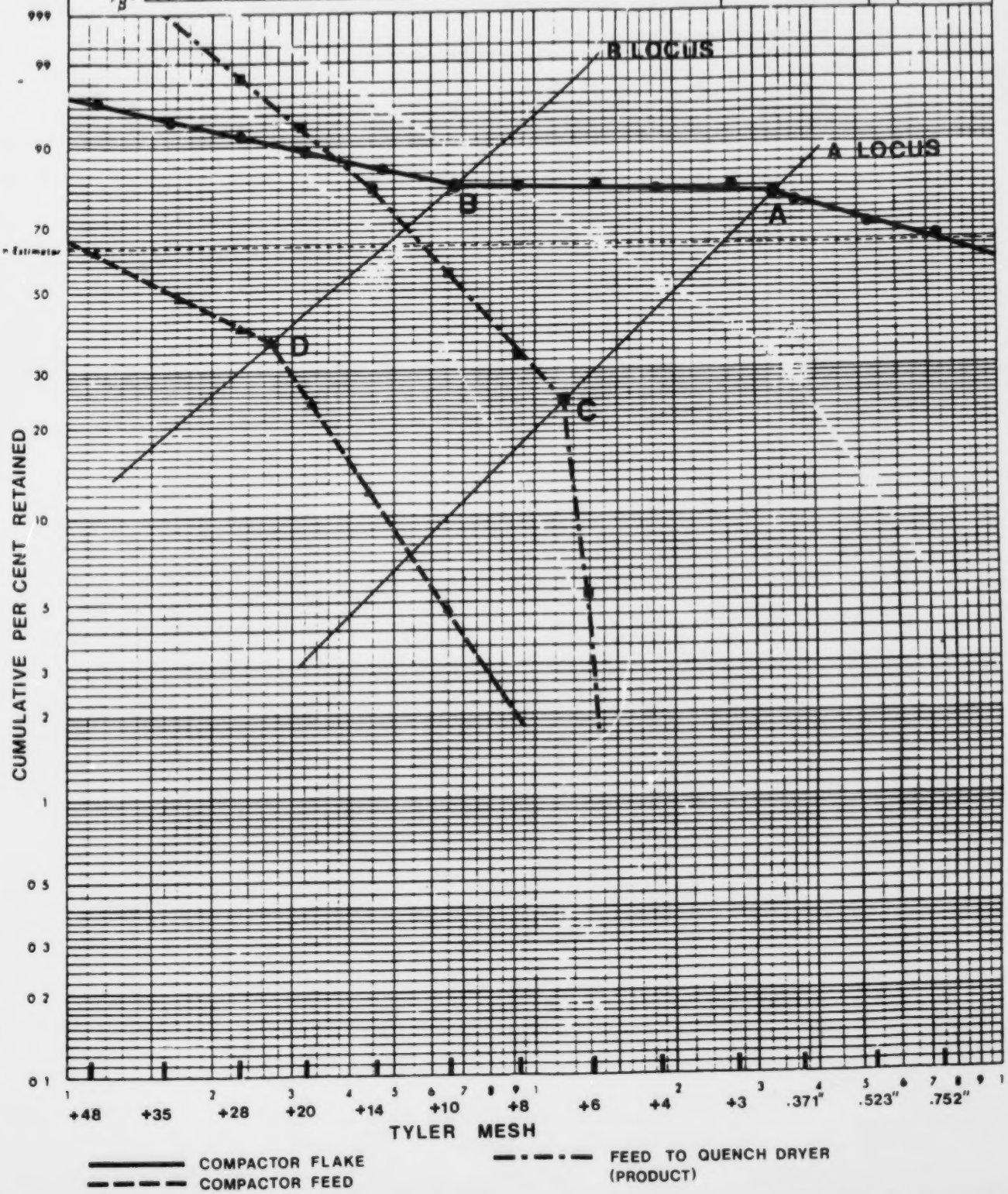
Weibull Probability by 2 Cycle Log

FIGURE 2.2

Test Number 1	Article and Source PCS CORY COMPACTOR FLAKE	Sample Size	N
Date	Type of Test SCREEN ANALYSIS	Shape	$\hat{\beta}$
P_μ	Mean $\hat{\mu}$	Characteristic Life	$\hat{\eta}$
$\hat{\beta}$		Minimum Life	$\hat{\gamma}$



observation is that the overall distribution can be defined by:

. the d75 of the compactor flake or some other measure of the particle size distribution upper size analysis.

. the locus of the coarse turning point A. As shown in Figure 2.2, turning point C of the product to the quench dryer particle size distribution lies on locus A.

. the locus of the fine turning point B. As shown in Figure 2.2, the turning point D of the compactor feed size distribution lies on locus B.

The loci A and B were observed experimentally to follow one another in a predictable way. To a good approximation these loci are linear over the range of flake particle size distributions studied.

Appendix C describes the Weibull probability distribution and defines mathematical procedures for use in the identification of compactor flake particle size distributions and other circuit particle size distributions. The mathematical procedure is called a decomposition.

From Appendix C, the cumulative particle size distribution H(x) for compactor flake is of the form:

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$$H(x) = \sum_{i=1}^{2} a_i \exp(-z_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where $z_i = (\log(x/x_{bi})^{\beta_i}$

Equation (3) implies that the flake consists of two components, a coarse and a fines fraction. These fractions have shape parameters β_i and x_{bi} and relative proportions a_i. Figure 2.3 shows the result of parameter identification for the A circuit #1 compactor. It shows the cumulative log-Weibull probability distribution with the following parameters:

$\beta_1 = 2.5779 \qquad x_{b1} = 0.2010 \qquad a_1 = 0.7953$

$\beta_2 = 2.9283 \qquad x_{b2} = 0.0029 \qquad a_2 = 0.2047$

The coarse density distribution (#1 above) is also shown on Figure 2.3. These parameters are related to compactor internal variables. The locus rules stated above define the turning points in Figure 2.2 in terms of the shape parameters of the compactor feed and granular product size distributions, which in turn defines the parameters x_{bi}. The determination of the variation of the shape parameters of the compactor flake distributions will require more plant testing.

A basic experimental design is proposed which will provide sets

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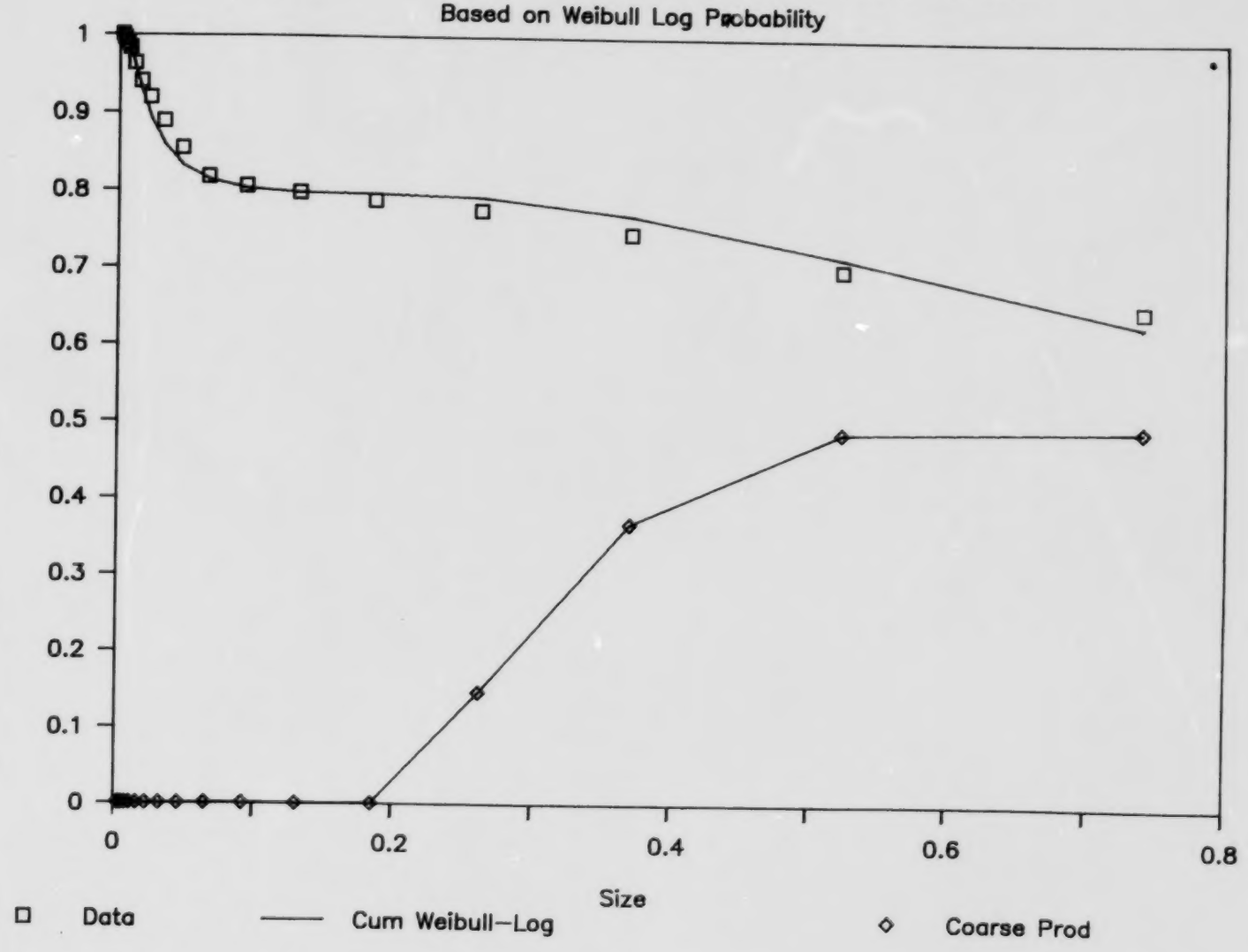
Figure 2.3 – Calculated Flake PSD



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of particle size distributions together with key compactor internal conditions. The objective of the analysis will be to relate compactor conditions to flake particle size distribution shape parameters.

In simpler terms the above analysis leads to the conclusion that it is possible to predict the particle size distribution of compactor flake given the following:

. the d75 of the compactor flake.

. the screen apertures for the primary and secondary screens.

Thus, the prediction strategy becomes one of relating the d75 to the internal operational variables of the compactor. Clearly, compressive pressure which relates to flake strength is a primary determinant of the d75.

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3.0 IMPACTOR PRINCIPLES

A potash impactor consists of a housing which contains rotating hammers. The feed material drops onto these hammers which break the material by impact. The rotation rate of the impactor is variable and this rate has a bearing on the production rate and grinding efficiency.

Impactors function almost like fans. Consequently, the flow through the mill is plug flow and the unit has a small hold-up weight W. The residence time distribution is constant and is given by the relationship:

$$t_r = W/T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where t_r is the retention time, W is the hold-up weight, and T is the mass flow rate. This retention time is constant for all particle sizes. The residence time distribution is a delta function and P_i the fraction of particle size i in the product:

$$P_i = (1/T) \int \delta(t-t_r) M_i dt = M_i(t_r)/T \quad \ldots\ldots\ldots\ldots (5)$$

If the mass flow rate through the mill is T tonnes per hour the rate of change of the mass of the ith size fraction M_i is given

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by the system of differential equations:

$$dM_i/dt = -S_i M_i + \sum_{j=1}^{i-1} b_{ij} S_j M_j \quad \ldots\ldots\ldots\ldots\ldots (6)$$

where the vector S_i describes the rate of loss of material from the ith size interval. This function is called the selection function in the grinding literature. It has the dimensions of $time^{-1}$.

The matrix b_{ij} describes the disappearance of material from the jth size interval over the finer size intervals $i=j+1, j+2, \ldots n$. Since mass is conserved in the impactor then:

$$\sum_{k=j+1}^{n} b_{kj} = 1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6.1)$$

The matrix b_{ij} is called the breakage matrix or in the case of an impactor the breakage function, because in this case it has a special feature. To see this, the following cumulation of the breakage matrix is made:

$$B_{ij} = \sum_{k=j+1}^{n} b_{kj} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

This matrix in the case of a potash impactor is constant for constant differences i-j. For example:

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$$B_{21} = B_{42} = B_{63} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Such a breakage function $b_{i,j}$ depends only on the difference between the jth size fraction and the finer ith size fraction. It is said to be difference similar. Such a grinding characteristic is common for monocrystalline material. In the case of potash the characteristic applies also to mine run ore. This is because the crystal lattices of halite (NaCl) and sylvite (KCl) are very similar. This causes the bonding between halite and sylvite crystals to be such that the material behaves under breakage as if it were a homogeneous solid.

The solution to equation (5) is subject to the following initial and final conditions:

$$M_i(t=0) = T\,F_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

$$M_i(t=t_r) = T\,P_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

where F_i is the feed particle size distribution and P_i is the product particle size distribution or the solution to equation (5) at time t_r, the residence time in the impactor.

Equation (5) normally consists of $n(n+3)/2-1$ unknown parameters. However, difference similarity reduces this to $2n-2$ parameters. In the case of the study tests, each impactor model in a circuit

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would require 32 parameters, 16 for the selection function and 16 for the breakage function. This was reduced to only six after it was learned that the typical selection and breakage functions were as shown in Figures 3.0 and 3.1. These functions can be described by the relations:

$$\ln S_i = s_1 + s_2(\ln x_i) + s_3(\ln x_i)^2 \quad \ldots\ldots\ldots\ldots (11)$$

$$B_{i,j} = b_1(x_i/x_j)^{b_2} + (1-b_1)(x_i/x_j)^{b_3} \quad \ldots\ldots (12)$$

Study results indicate that the parameters s_k for most mills will be a function of the impactor rpm and the parameter b_1 will be a function of the impactor gap.

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3.1 Calculation of the Product Size Distribution

Equation (5) is a set of linear simultaneous differential equations. The introduction of the breakage and selection function models given by equations (11) and (12) introduce a pronounced non-linearity which complicates both the solution process and the identification of the parameters b_κ and s_κ.

A solution can be obtained by recognizing that the differential equation can be reduced to the eigenvalue problem:

$$A Z - \Lambda Z \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13)$$

where the matrix $A = (B - I)S$ is formed from the breakage matrix B, the identity matrix I and the matrix S consisting of only diagonal elements $S_{ii} = S_i$. The diagonal matrix Λ consists of the net rates of breakage for all the size fractions and the matrix Z consists of the eigenvectors corresponding to these breakage rates as eigenvalues.

A numerical solution to the problem is obtained by forming the grinding matrix:

$$G = Z V Z^{-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (14)$$

where Z^{-1} is the inverse of Z and V is a diagonal matrix having

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the values $\exp(-t_r S_i)$.

The solution in matrix form at $t=t_r$ becomes:

$$P = G\,F \qquad \ldots\ldots(15)$$

Like the breakage function the matrices Z and G are lower triangular. For impactors the inverse G^{-1} exists so that the reverse transformation can be formed:

$$F = G^{-1}\,P \qquad \ldots\ldots(16)$$

The SPOC program called FINDBS was used to determine the parameters in equations (11) and (12) for all the tests analyzed in this study. The identification criterion was the minimization of the function:

$$\sum_{\text{tests}} \sum_{\text{sizes}} (M_{ij} - N_{ij})^2 \qquad \ldots\ldots(17)$$

The values N_{ij} are the data values and M_{ij} are the values produced by the solution to equation (6) for a given set of breakage and selection function parameters.

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Figure 3.0 – PCS A Circuit Impactor

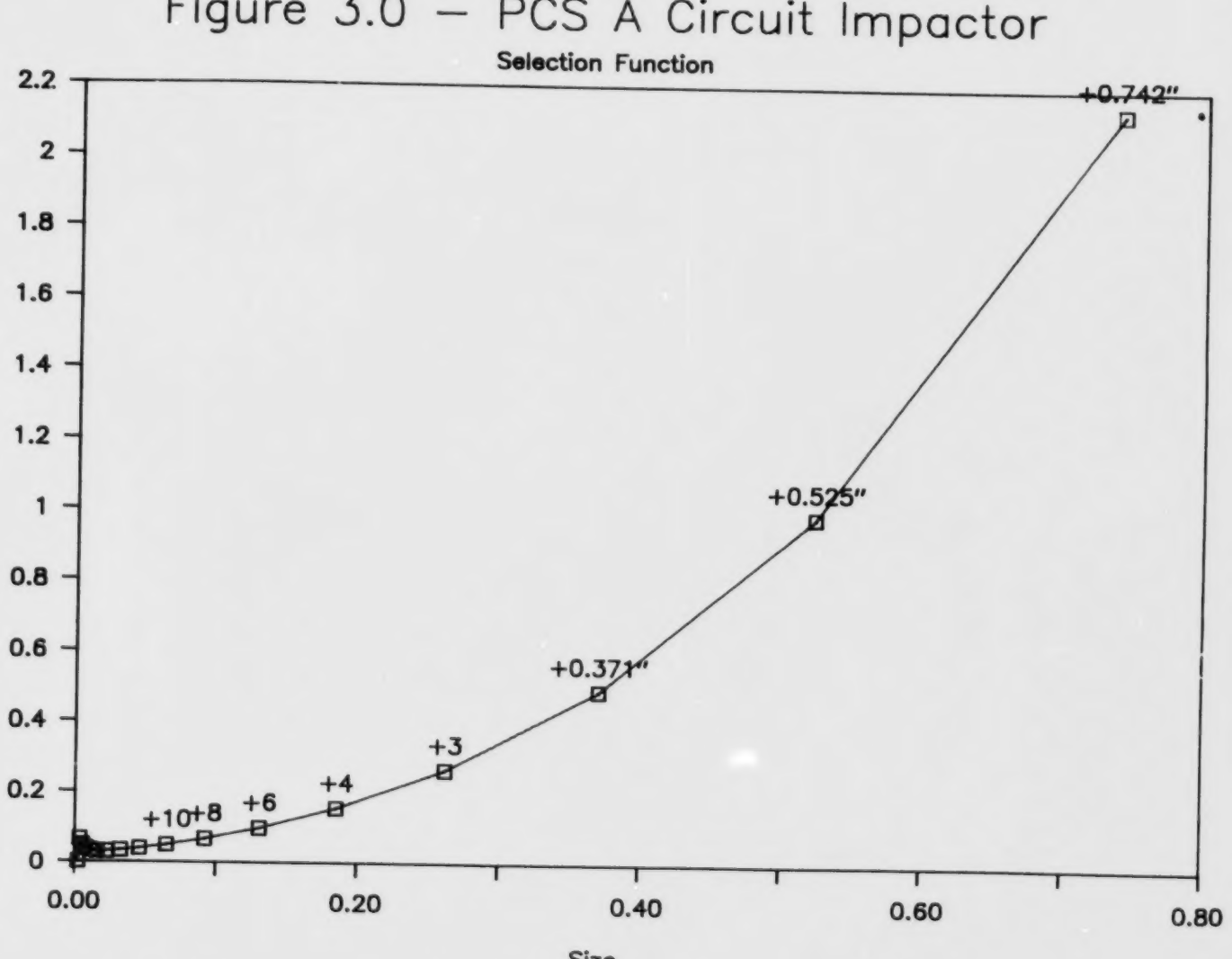

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Figure 3.1 – PCS "A Circuit" Impactor

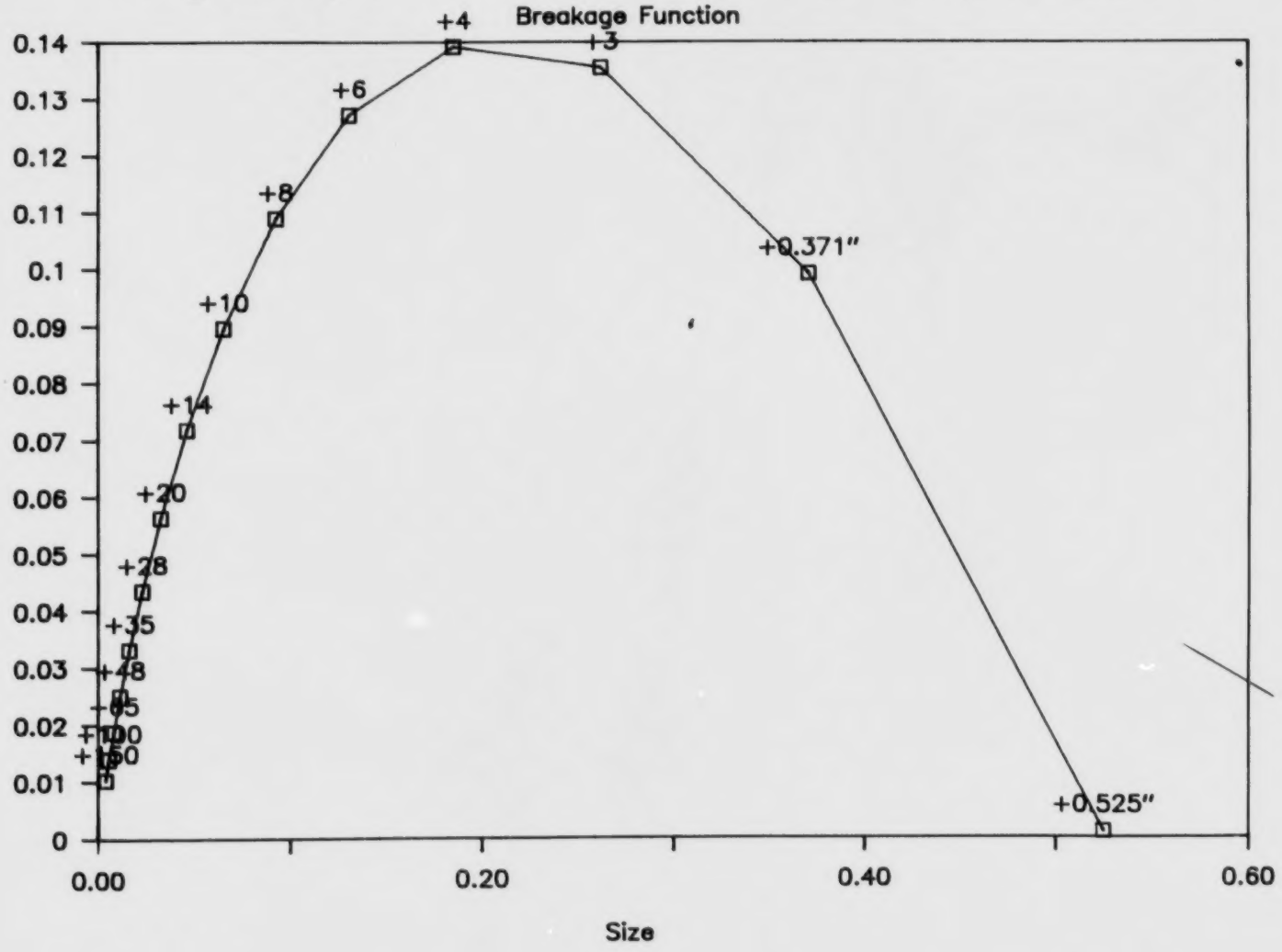

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Figure 3.2 – Compactor/Impactor

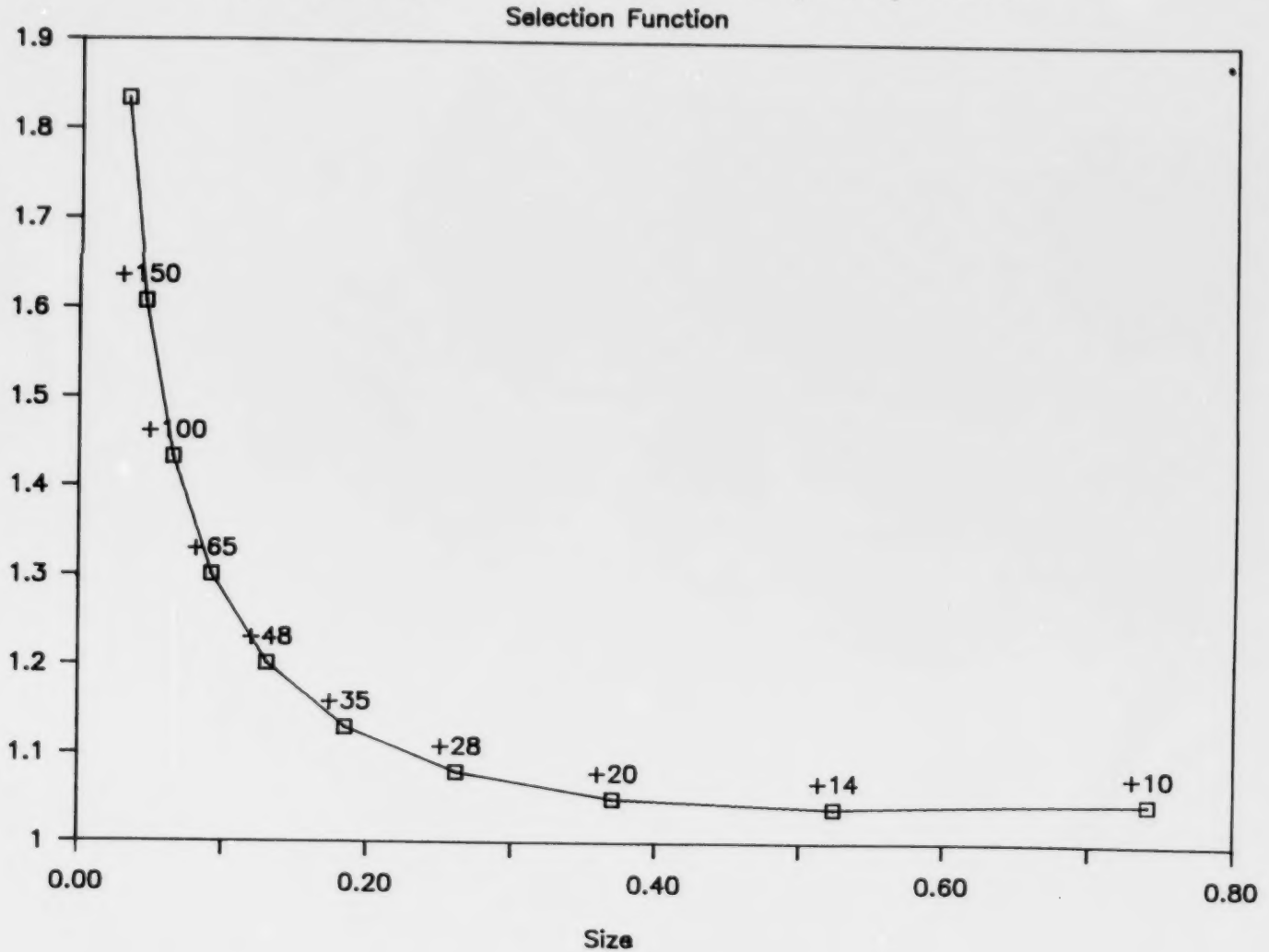

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Figure 3.3 – Compactor/Impactor

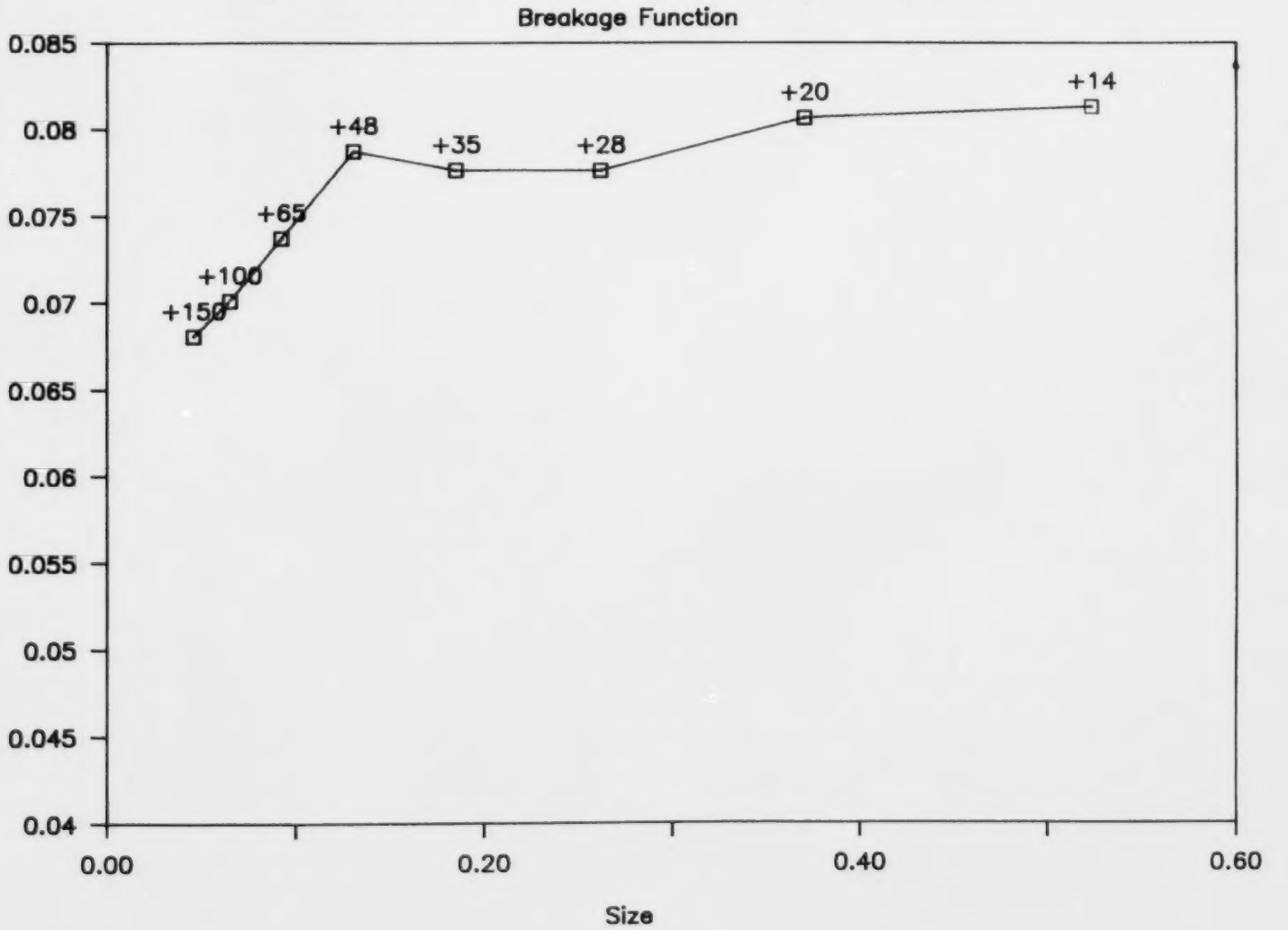

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Figure 3.4 – PCS Cory Feed to Screens

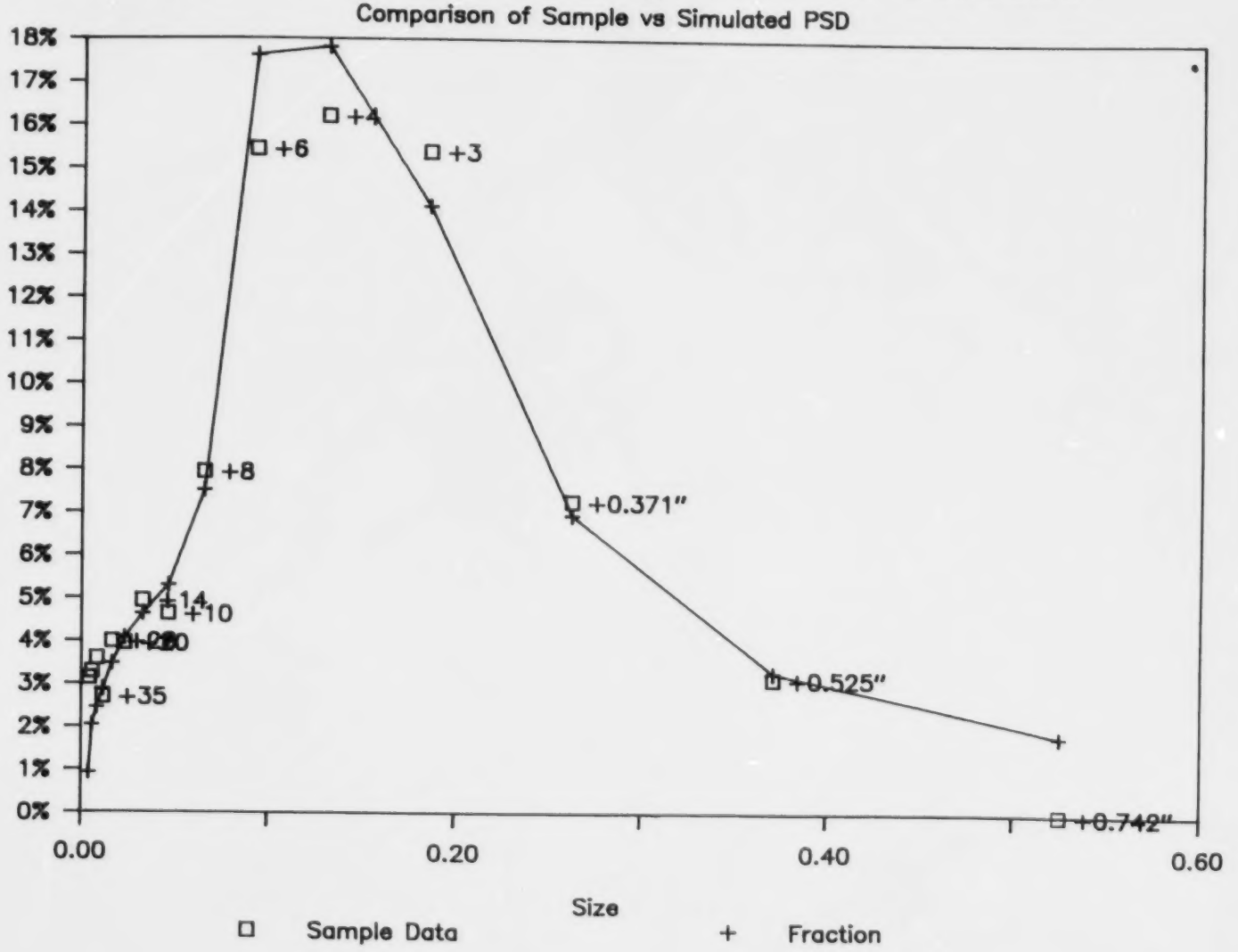

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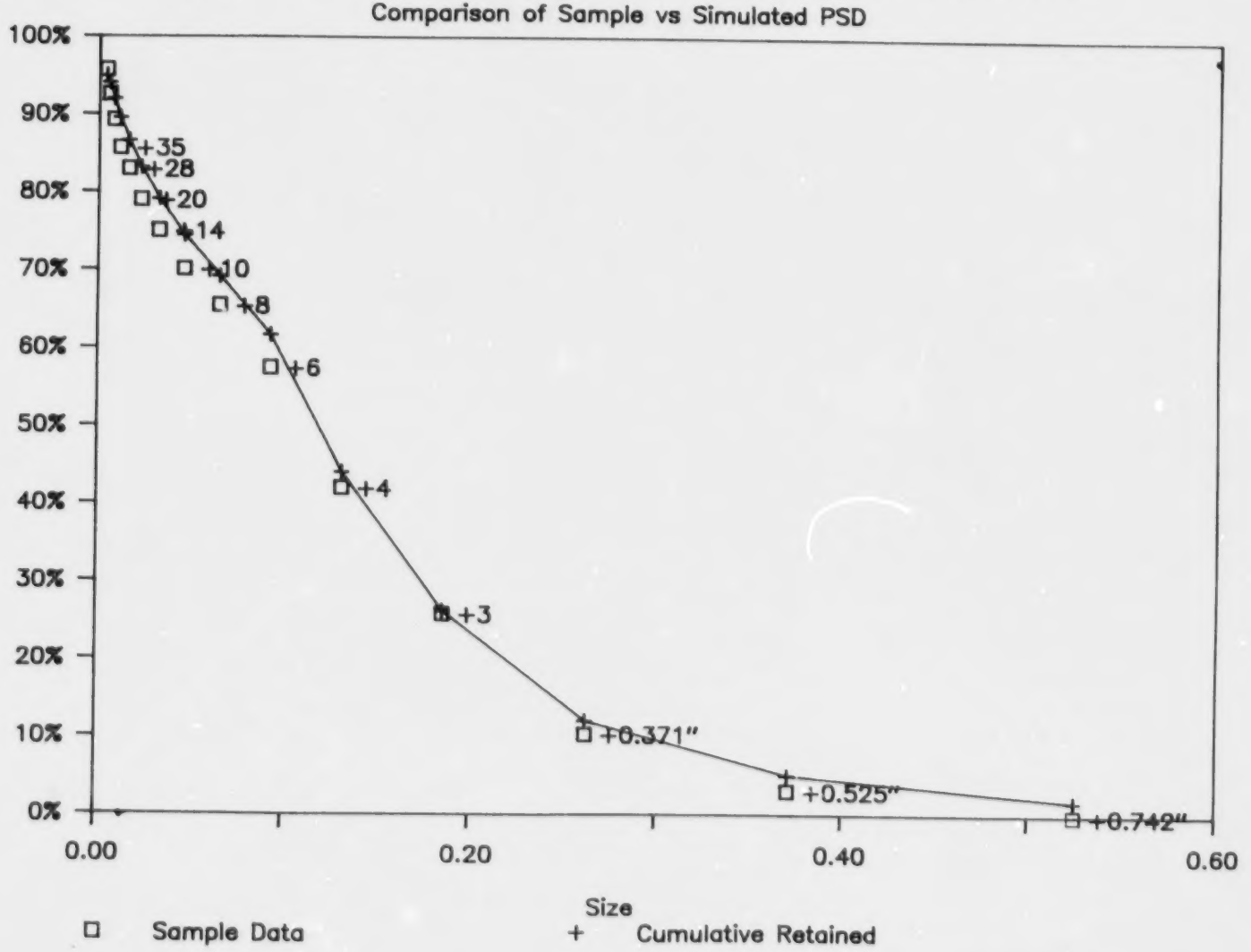
Figure 3.5 – PCS Cory Feed to Screens



4.0 COMPACTOR/IMPACTOR MODEL

Success with modelling the impactor function prompted an attempt to develop a modelling approach to compaction based upon the above impactor model. The formalism consisted of treating the combined impactor compactor model as a sequence of upgrading, selection and flake breakage. The equivalent of equation (15) in this case would be:

$$P = U\ H\ F \quad \ldots\ldots\ldots\

flow relative to the compactor feed mass flow.

Table B.2 of Appendix B shows the result of combining the impactor model for the bypass stream with the combined model for the flake. The key comparison is the predicted screen feed particle size distribution shown as Figure 3.4 and Figure 3.5. These results provide an indication of the progress that the study has made toward obtaining a basis for circuit simulation of the compactor/impactor portion of the circuit. With the exception of one or two points the theoretical curve matches the sample data well over a considerable size range. The cumulative particle size distribution displays the characteristic Weibull features such as the two-tailedness that was observed in all the sampled data.

Figure 3.2 and Figure 3.3 show the selection and breakage functions for the combined compactor/impactor model. For the important size fractions, the model predicts a flat selection function and a flat breakage function over the important particle size range.

The upgrading function representing the combined effects of all the matrix operations shown in equation (17) is uniform for the coarser size fractions. The finer size fractions have a markedly higher upgrading probability illustrating the way they provide the mortar for compaction. A study of the flake work index and

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these probability ratios, that can be derived from the matrix model, may be useful in determining quality control limits on flake.

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5.0 COMPACTION SCREENS

The screens employed at the PCS Cory mine at the time of testing were Tyler units. Since these were due to be replaced by double deck screens, the study concentrated on the double deck type as these are more commonly used in the Saskatchewan potash mines. The screen data used in the study was obtained from the PCS Lanigan circuit which employs double deck screens similar to the ones that have been implemented at PCS Cory since the time of the study tests. The model used to study these units is due to Plitt and Flintoff and is part of the SPOC library. The model is based upon the use of a partition function which specifies the shape of the separation function between the feed and product screens. The form employed in the model is:

$$P(d) = 1 - \exp(-k(d/d50c)^M \quad \ldots\ldots\ldots\ldots\ldots\ldots (19)$$

where the value k was found to be 0.685. The parameter M which relates to the fineness of separation was found to be 29.34 for the upper deck and 37.38 for the lower deck averaged over all the polishing and compaction screens. This parameter was determined by performing a non-linear least squares fit to the experimental data. Table 4.1 shows a comparison of the results of applying the Karra screen model KSCRN from the SPOC library to the polishing screens in the Lanigan circuit based upon the use of this averaged partition function and d50c values obtained also by non-

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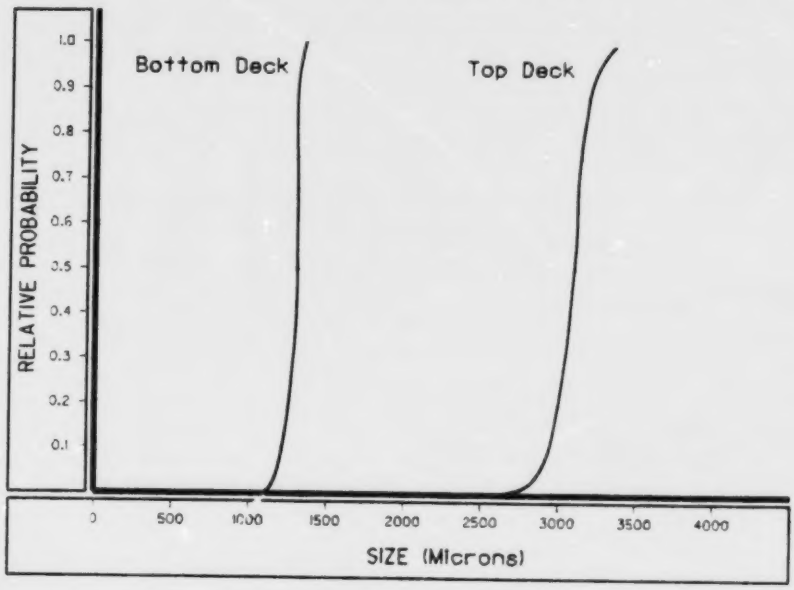
FIGURE 5.0

POLISHING SCREEN PARTITION FUNCTIONS



COMPACTION SCREEN #1 PARTITION FUNCTIONS

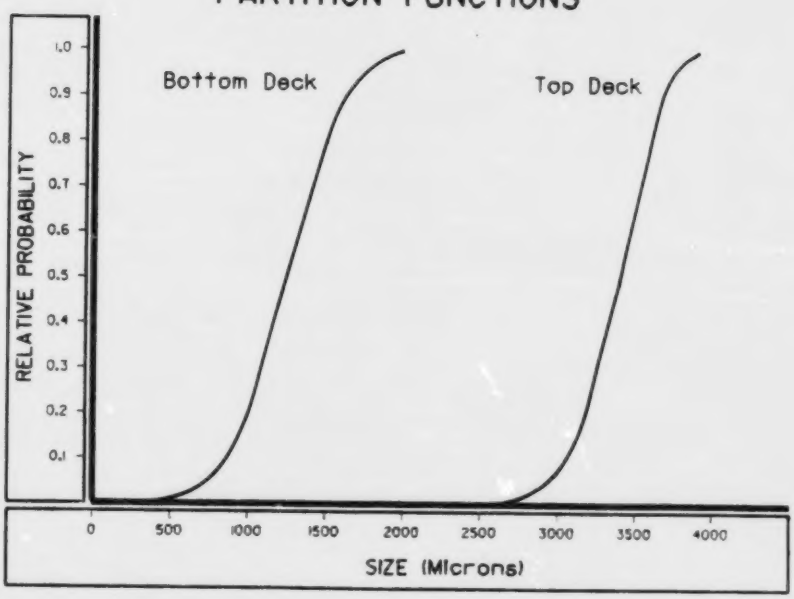


TABLE 4.1

SCREEN MASS BALANCE COMPARISION

PAGE 1

PCS LANIGAN COMPACTOR

POLISHING SCREENS

MASS FLOWS

	Tons	+5/8	+3/8	+3	+4	+6	+8	+10	+14	+20
Feed										
Balance #1 Analysis		0.0%	0.0%	0.0%	0.0%	6.6%	27.3%	22.4%	20.5%	8.7%
Balance #2 Analysis		0.0%	0.0%	0.0%	0.0%	6.5%	28.5%	23.5%	18.4%	9.5%
Balance #1 Tonnes	144.1	0.0	0.0	0.0	0.0	9.5	39.3	32.3	29.5	12.5
Balance #2 Tonnes	143.8	0.0	0.0	0.0	0.0	9.3	40.9	33.8	26.4	13.6
Difference	-0.3	0.0	0.0	0.0	0.0	-0.2	1.6	1.5	-3.1	1.0
U/S										
Balance #1 Analysis		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	15.2%	34.7%
Balance #2 Analysis		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	16.0%	33.9%
Balance #1 Tonnes	38.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.9	13.5
Balance #2 Tonnes	38.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.2	13.2
Difference	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	-0.3
Product										
Balance #1 Analysis		0.0%	0.0%	0.0%	0.0%	0.2%	36.2%	40.9%	22.0%	0.4%
Balance #2 Analysis		0.0%	0.0%	0.0%	0.0%	0.0%	35.8%	39.8%	23.8%	0.4%
Balance #1 Tonnes	85.0	0.0	0.0	0.0	0.0	0.2	30.8	34.8	18.7	0.3
Balance #2 Tonnes	84.8	0.0	0.0	0.0	0.0	0.0	30.4	33.7	20.1	0.3
Difference	-0.2	0.0	0.0	0.0	0.0	-0.2	-0.4	-1.0	1.4	-0.0
O/S										
Balance #1 Analysis		0.0%	0.0%	0.0%	0.0%	45.9%	53.5%	0.3%	0.1%	0.2%
Balance #2 Analysis		0.0%	0.0%	0.0%	0.0%	46.6%	52.8%	0.3%	0.1%	0.2%
Balance #1 Tonnes	20.3	0.0	0.0	0.0	0.0	9.3	10.9	0.1	0.0	0.0
Balance #2 Tonnes	20.0	0.0	0.0	0.0	0.0	9.3	10.5	0.1	0.0	0.0
Difference	-0.3	0.0	0.0	0.0	0.0	-0.0	-0.3	-0.0	-0.0	-0.0
Network Imbalance										
Balance #1	-0.0	0.0	0.0	0.0	0.0	0.0	-2.3	-2.5	4.9	-1.3
Balance #2	0.0	0.0	0.0	0.0	0.0	-0.0	-0.0	0.0	-0.0	0.0

TABLE 4.1

SCREEN MASS BALANCE COMPARISION

PAGE 2

PCS LANIGAN COMPACTOR

POLISHING SCREENS

MASS FLOWS

	+28	+35	+48	+65	+100	+150	+200	-200	Total
Feed									
Balance #1 Analysis	4.7%	2.4%	2.0%	1.4%	0.9%	3.1%	0.0%	0.0%	100.0%
Balance #2 Analysis	5.0%	2.5%	1.9%	1.3%	0.8%	0.6%	0.6%	1.0%	100.0%
Balance #1 Tonnes	6.8	3.5	2.9	2.0	1.3	4.5	0.0	0.0	
Balance #2 Tonnes	7.2	3.7	2.7	1.9	1.2	0.8	0.9	1.4	
Difference	0.5	0.2	-0.2	-0.1	-0.1	-3.7	0.9	1.4	
U/S									
Balance #1 Analysis	18.9%	9.6%	6.6%	4.5%	2.9%	1.8%	2.2%	3.6%	100.0%
Balance #2 Analysis	18.2%	9.2%	7.0%	4.8%	3.1%	2.0%	2.2%	3.6%	100.0%
Balance #1 Tonnes	7.3	3.7	2.6	1.7	1.1	0.7	0.9	1.4	
Balance #2 Tonnes	7.1	3.6	2.7	1.9	1.2	0.8	0.9	1.4	
Difference	-0.3	-0.2	0.2	0.1	0.1	0.1	0.0	0.0	
Product									
Balance #1 Analysis	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Balance #2 Analysis	0.2%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Balance #1 Tonnes	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
Balance #2 Tonnes	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	
Difference	-0.0	-0.0	0.0	0.0	0.0	0.0	0.0	0.0	
O/S									
Balance #1 Analysis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Balance #2 Analysis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Balance #1 Tonnes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Balance #2 Tonnes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Network Imbalance									
Balance #1	-0.7	-0.4	0.3	0.3	0.2	3.8	-0.9	-1.4	
Balance #2	0.0	-0.0	0.0	-0.0	0.0	-0.0	0.0	-0.0	

linear least squares fitting. The model used for fitting the data was a modified version of HCAL, the SPOC routine intended for calibrating hydrocyclones. By using HCAL in this way, it is possible to avoid having to estimate correction factors for oversize, halfsize, deck and nearsize that are used in the Karra screen model.

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5.1 Parameter Identification in Compaction Circuits

The accuracy of the Karra screening model is sufficient to conclude that no further testing is needed in order to develop a screening model and that the Karra model can be used for potash circuit simulation. It is planned to make a few cosmetic changes to HCAL in order to identify this model with screens rather than hydrocyclones. Beyond this, there is ample justification for writing FORTRAN code to combine the following as a combined process parameter identification package:

. determine impactor breakage and selection functions using only the applicable sections of FINDBS that pertain to impactors.

. determine d50c, M and k values for the screen partition function that pertain to the upper and lower decks of a double deck screen. This is the essential program logic of HCAL.

. determine the particle size shape parameters for all appropriate particle size distributions.

The above program functions would all share a common identification subroutine, namely the Powell algorithm BOTM. The three functions listed above would be callable separately from a

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circuit test mainline or from the executive section of the SIMBAL program.

A Kilborn project has been scheduled for producing the above software in 1989.

6.0 PCS CORY PLANT TESTS

The PCS Cory "A Circuit" was sampled with the results as shown in Table A.1 in Appendix A. A sequence of three tests were performed on consecutive days when it was judged that the circuit was stable at essentially the same production rate, producing flake of comparable good quality. In all three tests the compactor roll pressure, feed pressure, rpm and flake temperature were judged to be constant for the purpose of model building. Similarly, the impactor operation was judged to have constant operational parameters. Superficially, the three tests appeared to be replications of a single experiment.

The following is a summary of these conditions:

Roll Pressure	1500 psi
Flake Thickness	0.479 inches
Feed Temperature	133 Deg F
Impactor Gaps	0.75 inches
Production Rate	29 tonnes per hour (Approximate)

In the normal method of analysis, equation (1) is used to determine compactor production, followed by a balance on the screens assuming an observed split function. This specifies the two circulating loads. This process is repeated by trial and error until a reasonable amount of coherence is observed in the

overall trial balance for each size fraction. In this way the observed screen analyses are used indirectly to determine the mass balance. In spite of the obvious limitations of this methodology, this procedure is more or less standard and has been the basis for the analysis of circuit tests throughout the industry. It is laborious and critically dependent upon the model assumptions made about the screens.

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6.1 Mass Balancing

The tests were first analyzed to determine the variations across the three tests. The test data is tabulated in Table A.1 in Appendix A. As measured by the relative standard deviations averaged across the three tests, the hypothesis that the three tests constituted replication had to be questioned. According to measured production rates (granular product belt), the circuit was producing product at a uniform rate plus or minus one or two tonnes per hour and the compactors were deemed to be producing flake of uniform quality at a uniform rate, according to equation (1). Screen operation was unremarkable insofar as overloading was concerned. However, for the purposes of model development and demonstration, it was assumed that the data concealed a variable circulating load and the mass balancing procedure was constructed to assert this hypothesis. The particle size analysis of the relevant streams would dictate the degree of variation of the circulating load without invoking any vibrating screen model.

It might be noted that uncertainty regarding the circulating load is a fact of life with compactor operation. This makes the conventional mass balance across the impactors extremely difficult. At the outset, it was clear that a better method of circuit balancing would add measurably to the understanding of the circuit.

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The BILMAT program was used to analyze the three tests. The following assumptions were made in performing these mass balances:

. The relative standard deviations from the three tests were used to form the mass balancing criterion function for the BILMAT network three which was used to describe the balance by size analysis.

. The production rate was specified by equation (1) with a 10 percent weighting variance.

. The circulating load was set with a wider weighting variance in order for the balance to take different circulating load levels across the three tests.

. Circuit production was tightly weighted by the granular belt measurement.

. Size analysis was weighted heavily to force the screen analysis to match zero and very low values.

. The screen analysis was filtered to eliminate a few deviations from the experimentally observed log-Weibull probability shape.

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The above assumptions were formulated as a result of a considerable amount of trial and error. Balances were obtained during the same period using data from the Lanigan compaction circuit. Trials in both cases required the same weighting measures for both circuits. However, in the Lanigan case there were no replications of the data, but there were different levels of the secondary impactor rpm rate requiring a more arbitrary selection of the relative standard deviations of the size analysis variables.

The theory of small sample statistics would dictate that far more than three replications should be required to specify the BILMAT minimization function. However, successful usage of BILMAT in other application areas has usually involved a similar amount of arbitrariness. Replication is costly and it only serves to provide a measure of statistical variation and does not normally have a strong influence on individual test balances.

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6.2 PCS Cory Mass Balancing Results

Table B.1 in Appendix B shows the results of mass balancing for each of the three PCS Cory "A Circuit" tests. The match for the following variables is reasonably close to the sample data:

- Primary screen oversize
- Secondary screen oversize
- Dust
- Impactor discharge (screen feed)

These are the most important variables of the mass balance as they define the circulating load without resort to any screen model assumptions.

New feed does not balance as well as might be expected. The possibility exists that the feed characteristics may have been changing at the time of sampling. As a trial, the relative standard deviations were tightened on one of the tests and this improved the fit.

A check of key streams indicated that the mass balancing procedure preserved the experimentally observed log-Weibull characteristics of the particle size distribution.

The circulating load was found to be variable across the three

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screen tests. For example, the secondary oversize was found to vary between 126.2 to 198.4 with a mean of 181.1 tonnes per hour. Large changes to the relative standard deviations did not alter these figures significantly. This test recommends the BILMAT procedure as a means for determining circulating loads.

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6.3 PCS Lanigan Mass Balancing Results

The mass balancing procedure was tested using data from the PCS Lanigan compaction circuit in order to see how well it would function under greater circuit dimensionality. In this case, two circuits similar to the PCS Cory "A Circuit" were combined plus the polishing circuit as well. The impactors involved two stages of impact crushing to further complicate the balance. Remarkably, in spite of the greater dimensionality of the BILMAT network, better convergence was obtained and closer conformity was obtained between observed and balanced data. Since the data was obtained from testing conducted some time ago, it was not possible to obtain detailed information about the circumstances of the test or how stable the operation was at the time. From the mass balance data the circuit would appear to have been quite stable in spite of a very high circulating load. This conforms to the reason for the test, which was to test the effect on the production rate of adding additional screening units.

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7.0 RESULTS OF IMPACTOR ANALYSIS

Table B.2 of Appendix B shows mass balanced sample data taken around the impactor in the PCS "A Circuit". The impactor feed consists of flake from the two compactor units plus the secondary screen oversize. This material is broken in the impactor to provide feed to the compaction screens.

The identification of the breakage and selection function produced the following values of the breakage and selection function parameters employed in equations (11) and (12) as models:

$s_1 = 4.429$ $\quad b_1 = 10.89$

$s_2 = 2.54$ $\quad b_2 = 1.028$

$s_3 = 0.3218$ $\quad b_3 = 1.155$

The unit of time has been chosen such that $t_r = 181.1/T$. s_1 carries the units of $time^{-1}$, all other parameters are dimensionless. Using the criterion specified in equation (17) the value of this function was 87.5 for 42 degrees of freedom across the three tests. This corresponds to a standard deviation of the residuals for the model of 1.44 which is less than the error on the individual size distributions for any of the tests.

The relative asymptotic standard deviations for all six

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coefficients was independently estimated at less than 0.2 indicating the approximate level of confidence in the estimate of these parameters. A value of 0.5 or more would cause the rejection of the parameter from the model. In the case of the selection function this would cause the third term to be deleted and one would not interpret s_3 to be statistically significant.

Figure 3.0 and Figure 3.1 show the selection and breakage functions plotted as a function of particle size. Figure 3.1 is labelled to show how the largest size fraction +0.742 inch breaks after selection. The size fraction between +4 and -3 mesh receives the greatest amount of breakage from the +0.742 inch size interval. Owing to difference similarity the Figure 3.1 plot applies equally well to the +0.525 inch to -0.742 inch size interval if the labels are all shifted one to the left. This rule continues on for application to the finer size fractions of the impactor feed.

From Figure 3.0, it can be seen that the efficiency of impaction in terms of the efficiency of breakage increases faster than exponentially since s_2 and s_3 are both greater than zero.

The PCS Lanigan data allowed the repeated determination of the above parameters at varying impactor rates. By so doing, it was possible to identify a relationship between the parameters s_1, b_2 and the impactor speed. The value s_1 and b_2 increase with rpm to

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produce the effect shown in Figure 7.0. However, the size distribution above the then current impactor speed was found to deteriorate, overloading the screens.

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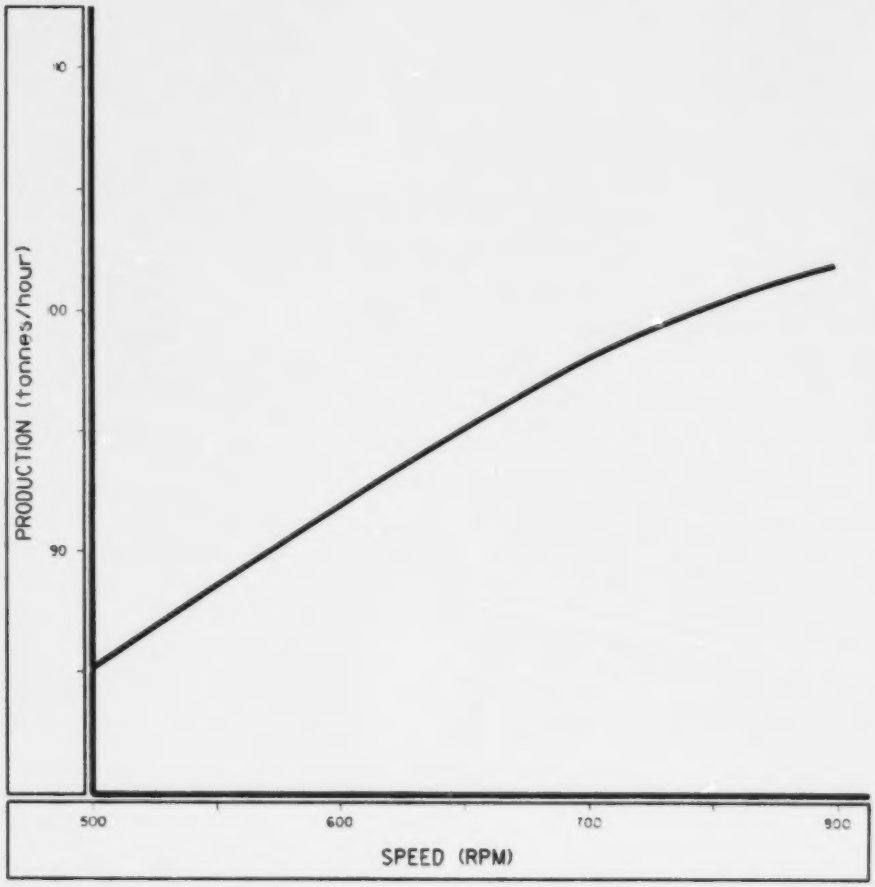
FIGURE 7.0

COMPACTOR CIRCUIT PRODUCTION VERSUS SECONDARY IMPACTOR SPEED



8.0 SUMMARY OF FINDINGS

All attempts to determine relationships between breakage and selection function parameters and the internal variables of the units broke down to a certain extent. This was because the tests were not designed to explore these relationships or the form of the relationships were not known. Therefore, there were built-in inadequacies in the experimental design. With a proper experimental design and a repeat of the analysis using the methods outlined above, it should be possible to identify important relationships with sufficient accuracy for simulation purposes. The relationships to be identified are:

. The relationship between impactor speed and the selection function parameter b_1. The formula obtained in the study was:

$$b_1 = 4.30\ (r/r_c)^{0.333} \quad \text{.....(20)}$$

. The relationship between the impactor speed and the ratio of the breakage function parameters b_2/b_3. This locates the maximum of the breakage function. In the PCS Lanigan tests it was found to increase with impactor speed which results in a downward shift in the breakage function maximum. The variation detected in the study was too slight to be judged statistically significant.

. The variation of the d75 of the flake particle size distribution with variations in compactor operating variables. None of the tests provide insight into this relationship owing to the limitations of the experimental design.

. The locus of the turning points A and B with respect to variations in the particle size distributions of the impactor feed and the product out of the screens to the quench dryer.

The loci A and B were identified fairly well through the PCS Cory tests.

The PCS Cory tests did not attempt to vary compactor variables. The goal of taking more than one test was to provide some replication mainly to determine the extent of circulating load variation during normal circuit operation. The results of the mass balancing show that there is considerable variation in the circulating load.

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9.0 FUTURE DIRECTION

The development of models for potash compaction and improvements in the operation of these circuits must continue to recognise the basic intractability of this process. The approach developed in this study holds considerable promise because it provides a means for quantifying the process, which is a requirement for advances in process control. The operating companies have experience and knowledge, even if the base of this knowledge may appear to be slim at times. In reality, the operation of the process is as much an art as a science, but there is a base of expertise. This base is confined to operators and development engineers and seems to be most evident among certain individuals who are dedicated to this part of the process.

These circumstances are typical of situations where the use of expert systems is proving worthwhile. However, in comparison to the expert systems applications that are documented there is a difference. This difference lies in the quantitative extent of the knowledge base and the level of the measurement technology. Successful expert systems seem to be based upon substantially better knowledge bases than that which is attainable in potash compaction at the present time.

Future work on model building should approach the compaction process with the goal of fully exploiting progress that has been

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made in expert systems. This would involve structuring the models of this study so that the above analysis of the circuit tests are displayed to the operator. He can begin to use the results of the analysis to make back-chaining judgements on the statistical state of the process. In this way the analysis tools of this study will add to the knowledge base of the expert system in an evolutionary way.

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10.0 REFERENCES

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(2) Banks, A. F. and Johanson, J. R., "Achieving Higher Production Rates Using Existing Roll Presses for Potash", I.B.A Conference, 1975.

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APPENDIX A

PCS CORY TEST DATA

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28-Feb-89

Table A.1 - PCS CORY COMPACTION TESTS Page 1

	STREAM NO	0.742	0.525	0.371	+3	+4	+6	+8	+10	+14	+20	+28
TEST #1												
CIRCUIT A												
CUMULATIVE												
NEW FEED	1								0.5%	13.4%	28.8%	41.3%
COMP A1 IN	2								0.5%	13.1%	27.8%	39.5%
COMP B1 IN	3								6.1%	35.0%	56.3%	68.8%
COMP A1 OUT	4	64.9%	69.9%	74.5%	77.4%	78.7%	79.7%	80.5%	81.7%	85.4%	88.9%	91.9%
COMP B1 OUT	5	66.1%	72.5%	80.2%	83.4%	84.4%	85.1%	85.8%	86.3%	87.4%	89.0%	91.0%
SCREEN FEED	6	1.4%	4.8%	11.6%	25.5%	41.3%	57.1%	65.3%	70.1%	74.9%	78.6%	82.6%
PRIM O/S	7	1.8%	6.1%	16.3%	33.9%	55.5%	74.7%	85.3%	90.7%	95.5%	98.4%	99.5%
DUST	8									0.7%	7.1%	19.3%
SEC O/S	9	2.2%	5.1%	17.6%	44.1%	70.6%	94.5%	98.6%	99.3%	99.5%	100.0%	100.0%
PROD	10						5.5%	33.2%	55.7%	82.2%	94.5%	98.1%
FRACTION												
NEW FEED	1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	12.9%	15.4%	12.5%
COMP A1 IN	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	12.6%	14.7%	11.7%
COMP B1 IN	3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.1%	28.9%	21.3%	12.5%
COMP A1 OUT	4	64.9%	5.0%	4.6%	2.9%	1.3%	1.0%	0.8%	1.2%	3.7%	3.5%	3.0%
COMP B1 OUT	5	66.1%	6.4%	7.7%	3.2%	1.0%	0.7%	0.7%	0.5%	1.1%	1.6%	2.0%
SCREEN FEED	6	1.4%	3.4%	6.8%	13.9%	15.8%	15.8%	8.2%	4.8%	4.8%	3.7%	4.0%
PRIM O/S	7	1.8%	4.3%	10.2%	17.6%	21.6%	19.2%	10.6%	5.4%	4.8%	2.9%	1.1%
DUST	8	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	6.4%	12.2%
SEC O/S	9	2.2%	2.9%	12.5%	26.5%	26.5%	23.9%	4.1%	0.7%	0.2%	0.5%	0.0%
PROD	10	0.0%	0.0%	0.0%	0.0%	0.0%	5.5%	27.7%	22.5%	26.5%	12.3%	3.6%

KILBORN

	STREAM NO	0.742	0.525	0.371	+3	+4	+6	+8	+10	+14	+20	+28
TEST #2												
CIRCUIT A												
CUMULATIVE												
NEW FEED	1								1.4%	25.2%	51.8%	69.2%
COMP A1 IN	2								1.6%	33.3%	59.3%	75.6%
COMP B1 IN	3								1.9%	36.9%	67.4%	85.3%
COMP A1 OUT	4	75.3%	78.8%	81.5%	83.5%	84.3%	84.9%	85.4%	85.9%	89.1%	91.6%	94.1%
COMP B1 OUT	5	53.9%	76.4%	82.6%	84.3%	85.1%	85.6%	86.1%	86.7%	88.4%	90.5%	92.2%
SCREEN FEED	6	0.0%	3.1%	15.3%	32.4%	45.8%	58.8%	65.6%	70.0%	74.8%	79.0%	83.6%
PRIM O/S	7	3.8%	7.2%	25.3%	46.1%	64.1%	80.2%	88.1%	92.3%	96.8%	99.1%	99.6%
DUST	8									10.8%	16.5%	25.1%
SEC O/S	9	3.1%	8.4%	28.5%	52.6%	76.5%	95.3%	98.7%	99.4%	99.6%	99.7%	100.0%
PROD	10						8.1%	33.5%	56.0%	81.0%	94.3%	97.6%
FRACTION												
NEW FEED	1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.4%	23.8%	26.6%	17.4%
COMP A1 IN	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.6%	31.7%	26.0%	16.3%
COMP B1 IN	3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.9%	35.0%	30.5%	17.9%
COMP A1 OUT	4	75.3%	3.5%	2.7%	2.0%	0.8%	0.6%	0.5%	0.5%	3.2%	2.5%	2.5%
COMP B1 OUT	5	53.9%	22.5%	6.2%	1.7%	0.8%	0.5%	0.5%	0.6%	1.7%	2.1%	2.4%
SCREEN FEED	6	0.0%	3.1%	12.2%	17.1%	13.4%	13.0%	6.8%	4.4%	4.8%	4.2%	4.6%
PRIM O/S	7	3.8%	3.4%	18.1%	20.8%	18.0%	16.1%	7.9%	4.2%	4.5%	2.3%	0.5%
DUST	8	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.8%	5.7%	8.6%
SEC O/S	9	3.1%	5.3%	20.1%	24.1%	23.9%	18.8%	3.4%	0.7%	0.2%	0.1%	0.3%
PROD	10	0.0%	0.0%	0.0%	0.0%	0.0%	8.1%	25.4%	22.5%	25.0%	13.3%	3.3%

KILBORN

	STREAM NO	0.742	0.525	0.371	+3	+4	+6	+8	+10	+14	+20	+28
TEST #3												
CIRCUIT A												
CUMULATIVE												
NEW FEED	1								6.2%	35.3%	56.5%	73.2%
COMP A1 IN	2								5.8%	34.3%	54.3%	70.0%
COMP B1 IN	3								9.4%	48.5%	70.9%	86.3%
COMP A1 OUT	4	71.0%	76.0%	78.8%	80.8%	81.8%	82.2%	82.7%	84.5%	88.4%	91.2%	93.6%
COMP B1 OUT	5	50.0%	76.1%	83.0%	86.2%	87.1%	87.7%	88.3%	89.0%	90.3%	91.9%	93.5%
SCREEN FEED	6	3.0%	3.2%	11.6%	25.8%	38.6%	52.3%	59.6%	65.1%	70.7%	75.8%	80.9%
PRIM O/S	7	0.0%	3.3%	15.9%	38.7%	57.7%	74.5%	83.3%	89.5%	95.4%	98.7%	99.4%
DUST	8									0.8%	8.8%	24.7%
SEC O/S	9	2.0%	3.1%	21.2%	47.5%	73.6%	95.1%	98.8%	99.5%	99.7%	99.8%	100.0%
PROD	10						4.4%	28.7%	50.3%	80.6%	93.8%	97.6%
FRACTION												
NEW FEED	1	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	6.2%	29.1%	21.2%	16.7%
COMP A1 IN	2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.8%	28.5%	20.0%	15.7%
COMP B1 IN	3	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.4%	39.1%	22.4%	15.4%
COMP A1 OUT	4	71.0%	5.0%	2.8%	2.0%	1.0%	0.4%	0.5%	1.8%	3.9%	2.8%	2.4%
COMP B1 OUT	5	50.0%	26.1%	6.9%	3.2%	0.9%	0.6%	0.6%	0.7%	1.3%	1.6%	1.6%
SCREEN FEED	6	3.0%	0.2%	8.4%	14.0%	13.0%	13.7%	7.3%	5.5%	5.6%	5.1%	5.1%
PRIM O/S	7	0.0%	3.3%	12.6%	22.8%	19.0%	16.8%	8.8%	6.2%	5.9%	3.3%	0.7%
DUST	8	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.8%	8.0%	15.9%
SEC O/S	9	2.0%	1.1%	18.1%	26.3%	26.1%	21.5%	3.7%	0.7%	0.2%	0.1%	0.2%
PROD	10	0.0%	0.0%	0.0%	0.0%	0.0%	4.4%	24.3%	21.6%	30.3%	13.2%	3.8%
TEST #2												
CIRCUIT A												
STANDARD DEVIATIONS (RELATIVE)												
NEW FEED	1	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	92.7%	30.7%	21.7%	13.9%
COMP A1 IN	2	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	86.7%	34.4%	22.8%	14.0%
COMP B1 IN	3	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	52.9%	12.2%	16.6%	14.5%
COMP A1 OUT	4	6.1%	15.7%	25.9%	18.4%	19.9%	37.4%	23.6%	45.5%	8.2%	14.3%	10.0%
COMP B1 OUT	5	12.1%	46.7%	8.8%	26.2%	9.1%	13.6%	13.6%	13.6%	18.3%	13.3%	16.3%
SCREEN FEED	6	83.6%	64.6%	24.8%	9.9%	8.8%	8.4%	7.8%	9.3%	7.4%	13.4%	9.8%
PRIM O/S	7	83.1%	12.3%	24.3%	10.5%	7.8%	7.6%	12.3%	15.6%	11.9%	14.5%	32.5%
DUST	8	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	115.6%	14.4%	24.4%
SEC O/S	9	19.7%	55.5%	19.0%	4.2%	4.5%	9.7%	7.7%	0.0%	0.0%	80.8%	74.8%
PROD	10	100.0%	100.0%	100.0%	100.0%	100.0%	25.9%	5.5%	1.9%	8.2%	3.5%	5.8%

KIMBERLIN

	STREAM NO	+35	+48	+65	+100	+150	-150
TEST #1							
CIRCUIT A							
CUMULATIVE							
NEW FEED	1	51.6%	67.6%	80.7%	91.7%	97.4%	100.0%
COMP A1 IN	2	49.5%	65.5%	79.1%	91.1%	97.3%	100.0%
COMP B1 IN	3	76.5%	85.9%	92.4%	96.7%	98.8%	100.0%
COMP A1 OUT	4	94.0%	96.3%	98.3%	98.9%	99.5%	100.0%
COMP B1 OUT	5	92.7%	94.7%	96.4%	97.9%	98.9%	100.0%
SCREEN FEED	6	85.6%	89.2%	92.4%	95.2%	97.2%	100.0%
PRIM O/S	7	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
DUST	8	33.3%	50.6%	64.7%	78.2%	87.6%	100.0%
SEC O/S	9	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
PROD	10	99.0%	99.5%	99.7%	99.8%	99.9%	100.0%
FRACTION							
NEW FEED	1	10.3%	16.0%	13.1%	11.0%	5.7%	2.6%
COMP A1 IN	2	10.0%	16.0%	13.6%	12.0%	6.2%	2.7%
COMP B1 IN	3	7.7%	9.4%	6.5%	4.3%	2.1%	1.2%
COMP A1 OUT	4	2.1%	2.3%	2.0%	0.6%	0.6%	0.5%
COMP B1 OUT	5	1.7%	2.0%	1.7%	1.5%	1.0%	1.1%
SCREEN FEED	6	3.0%	3.6%	3.2%	2.8%	2.0%	2.8%
PRIM O/S	7	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%
DUST	8	14.0%	17.3%	14.1%	13.5%	9.4%	12.4%
SEC O/S	9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PROD	10	0.9%	0.5%	0.2%	0.1%	0.1%	0.1%

KILBORN

Table A.1 - PCS CORY COMPACTION TESTS

	STREAM NO	+35	+48	+65	+100	+150	-150
TEST #2							
CIRCUIT A							
CUMULATIVE							
NEW FEED	1	82.6%	91.3%	94.4%	96.2%	98.1%	100.0%
COMP A1 IN	2	84.8%	91.1%	93.7%	95.3%	97.2%	100.0%
COMP B1 IN	3	92.8%	96.8%	97.9%	98.5%	99.1%	100.0%
COMP A1 OUT	4	95.7%	97.2%	98.0%	98.6%	99.2%	100.0%
COMP B1 OUT	5	94.5%	96.3%	97.4%	98.2%	99.0%	100.0%
SCREEN FEED	6	87.2%	90.6%	93.1%	95.2%	96.9%	100.0%
PRIM O/S	7	99.7%	99.9%	100.0%	100.0%	100.0%	100.0%
DUST	8	41.6%	58.4%	69.3%	78.7%	86.1%	100.0%
SEC O/S	9	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
PROD	10	98.6%	99.2%	99.4%	99.6%	99.8%	100.0%
FRACTION							
NEW FEED	1	13.4%	8.7%	3.1%	1.8%	1.9%	1.9%
COMP A1 IN	2	9.2%	6.3%	2.6%	1.6%	1.9%	2.8%
COMP B1 IN	3	7.5%	4.0%	1.1%	0.6%	0.6%	0.9%
COMP A1 OUT	4	1.6%	1.5%	0.8%	0.6%	0.6%	0.8%
COMP B1 OUT	5	1.6%	1.8%	1.1%	0.8%	0.8%	1.0%
SCREEN FEED	6	3.6%	3.4%	2.5%	2.1%	1.7%	3.1%
PRIM O/S	7	0.1%	0.2%	0.1%	0.0%	0.0%	0.0%
DUST	8	16.5%	16.8%	10.9%	9.4%	7.4%	13.9%
SEC O/S	9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PROD	10	1.0%	0.6%	0.2%	0.2%	0.2%	0.2%

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	STREAM NO	+35	+48	+65	+100	+150	-150	
TEST #3								
CIRCUIT A								
CUMULATIVE								
NEW FEED	1	82.9%	89.8%	93.4%	96.3%	98.6%	100.0%	
COMP A1 IN	2	79.6%	87.1%	90.6%	93.6%	97.0%	100.0%	
COMP B1 IN	3	93.6%	97.5%	98.3%	98.7%	99.2%	100.0%	
COMP A1 OUT	4	96.5%	96.9%	97.9%	98.6%	99.2%	100.0%	
COMP B1 OUT	5	96.1%	96.5%	97.5%	98.4%	99.1%	100.0%	
SCREEN FEED	6	85.4%	89.5%	92.5%	94.7%	96.7%	100.0%	
PRIM O/S	7	99.6%	99.8%	100.0%	100.0%	100.0%	100.0%	
DUST	8	41.4%	57.8%	69.1%	78.9%	86.5%	100.0%	
SEC O/S	9	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
PROD	10	98.7%	99.1%	99.6%	99.8%	99.8%	100.0%	
FRACTION								
NEW FEED	1	9.7%	6.9%	3.6%	2.9%	2.3%	1.4%	
COMP A1 IN	2	9.6%	7.5%	3.5%	3.0%	3.4%	3.0%	
COMP B1 IN	3	7.3%	3.9%	0.8%	0.4%	0.5%	0.8%	
COMP A1 OUT	4	1.9%	1.4%	1.0%	0.7%	0.6%	0.8%	
COMP B1 OUT	5	1.6%	1.4%	1.0%	0.9%	0.7%	0.9%	
SCREEN FEED	6	4.5%	4.1%	3.0%	2.2%	2.0%	3.3%	
PRIM O/S	7	0.2%	0.2%	0.2%	0.0%	0.0%	0.0%	
DUST	8	16.7%	16.4%	11.3%	9.8%	7.6%	13.5%	
SEC O/S	9	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
PROD	10	1.1%	0.4%	0.5%	0.2%	0.0%	0.2%	
TEST #2								
CIRCUIT A								MEAN
STANDARD DEVIATIONS (RELATIVE)								
NEW FEED	1	14.6%	37.4%	69.7%	78.4%	51.7%	25.0%	43.6%
COMP A1 IN	2	3.4%	43.5%	76.9%	83.3%	46.5%	4.4%	41.6%
COMP B1 IN	3	2.2%	44.6%	93.5%	101.5%	68.6%	17.6%	42.4%
COMP A1 OUT	4	11.0%	23.2%	41.4%	7.4%	0.0%	20.2%	21.6%
COMP B1 OUT	5	2.9%	14.4%	24.4%	29.0%	15.0%	8.2%	16.7%
SCREEN FEED	6	16.7%	8.0%	10.2%	13.1%	7.4%	6.7%	18.2%
PRIM O/S	7	63.7%	70.7%	81.6%	100.0%	100.0%	100.0%	32.0%
DUST	8	7.8%	2.2%	11.8%	16.9%	11.1%	4.8%	23.2%
SEC O/S	9	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	25.1%
PROD	10	8.2%	16.3%	47.1%	28.3%	81.6%	28.3%	21.1%

KILBORN

APPENDIX B

SIMULATION RESULTS

KILBORN

TABLE B.1

ESTIMATES OF NETWORKS 1 & 2 VARIABLES

STREAMS	SOLID FLOW RATES MEAS. VALUES	ESTIM. VALUES	RESID. VALUES	RELAT. ST.DEV	PULP PERCENT SOLIDS MEAS. VALUES	ESTIM. VALUES	RESID. VALUES	RELAT. ST.DEV
NEW FEED	.00	29.61	100.00	.00	.00	.00	100.00	.00
COMPA1 IN	26.70	27.09	1.44	2.67	.00	.00	100.00	.00
COMPB1 IN	35.60	34.84	2.13	3.56	.00	.00	100.00	.00
SCREEN FEED	198.40	158.51	20.11	19.84	.00	.00	100.00	.00
PRIM O/S	.00	126.19	100.00	.00	.00	.00	100.00	.00
DUST	.00	32.32	100.00	.00	.00	.00	100.00	.00
SEC O/S	.00	96.59	100.00	.00	.00	.00	100.00	.00
PROD	.00	29.61	100.00	.00	.00	.00	100.00	.00
COMPA1 OUT	.00	27.09	100.00	.00	.00	.00	100.00	.00
COMPB1 OUT	.00	34.84	100.00	.00	.00	.00	100.00	.00

ESTIMATES OF NETWORK 3 MASS FRACTIONS

STREAMS	NEW FEED MEAS. VALUES	ESTIM. VALUES	RESID. VALUES	RELAT. ST.DEV.	COMPA1 IN MEAS. VALUES	ESTIM. VALUES	RESID. VALUES	RELAT. ST.DEV.
+742	.00	-.00	100.00	.10	.00	.00	100.00	.10
+525	.00	-.00	100.00	.10	.00	.00	100.00	.10
+371	.00	-.00	100.00	.10	.00	.00	100.00	.10
+3	.00	-.00	100.00	.10	.00	.00	100.00	.10
+4	.00	-.00	100.00	.10	.00	.00	100.00	.10
+6	.00	-.00	100.00	.10	.00	.00	100.00	.10
+8	.00	-.00	100.00	.10	.00	.00	100.00	.10
+10	.50	.63	26.00	92.70	.50	.40	20.22	86.70
+14	12.90	23.64	83.26	30.70	12.60	1.12	91.10	34.10
+20	15.40	20.52	33.23	21.70	14.70	10.16	30.85	22.80
+28	12.50	11.20	10.40	13.90	11.70	12.80	9.39	14.00
+35	10.30	5.04	51.11	14.60	10.00	10.25	2.45	3.40
+48	16.00	14.03	12.32	37.40	16.00	19.19	19.94	43.50
+65	13.10	12.14	7.33	69.70	13.60	16.37	20.40	75.90
+100	11.00	8.17	25.72	78.40	12.00	17.03	41.88	93.30
+150	5.70	2.05	64.04	51.70	6.20	9.53	53.63	46.50
-150	2.60	2.60	.01	.10	2.70	3.14	16.38	4.40

STREAMS	COMPB1 IN MEAS. VALUES	COMPB1 IN ESTIM. VALUES	COMPB1 IN RESID. VALUES	COMPB1 IN RELAT. ST.DEV.	SCREEN FEED MEAS. VALUES	SCREEN FEED ESTIM. VALUES	SCREEN FEED RESID. VALUES	SCREEN FEED RELAT. ST.DEV.
-742	.00	.00	100.00	.10	1.40	1.34	4.54	93.60
+525	.00	.00	100.00	.10	3.40	3.14	7.52	64.60
-371	.00	.00	100.00	.10	6.80	7.28	7.09	21.80
-3	.00	.00	100.00	.10	13.90	15.40	10.76	9.90
+4	.00	.00	100.00	.10	15.80	16.22	2.63	8.50
+6	.00	.00	100.00	.10	15.80	15.46	2.13	8.40
+8	.00	.00	100.00	.10	8.20	7.97	2.82	7.80
+10	6.10	.24	96.04	52.90	4.80	4.63	3.18	9.30
+14	28.90	20.74	28.23	12.20	4.80	4.95	3.14	7.40
+20	21.30	16.43	22.88	16.60	3.70	3.96	7.13	13.40
+28	12.30	14.66	17.24	14.50	4.00	4.00	.09	9.80
+35	7.70	7.78	1.08	2.20	3.00	2.71	9.78	16.70
+48	9.40	13.17	40.06	44.60	3.60	3.61	.26	8.00
+65	6.50	12.52	92.64	93.50	3.20	3.30	3.22	10.20
+100	4.30	8.00	86.04	101.50	2.80	3.15	12.37	13.10
+150	2.10	3.44	63.66	68.60	2.00	2.01	.52	7.40
150	1.20	3.00	150.27	17.60	2.80	.85	69.53	6.70

STREAMS	PRIM O/S MEAS. VALUES	PRIM O/S ESTIM. VALUES	PRIM O/S RESID. VALUES	PRIM O/S RELAT. ST.DEV.	DUST MEAS. VALUES	DUST ESTIM. VALUES	DUST RESID. VALUES	DUST RELAT. ST.DEV.
-742	1.80	1.68	6.84	83.10	.00	.01	100.00	.10
+525	4.30	3.95	8.20	12.30	.00	.01	100.00	.10
-371	10.20	9.15	10.34	24.30	.00	.01	100.00	.10
-3	17.60	19.34	9.87	10.50	.00	.01	100.00	.10
+4	21.60	20.37	5.71	7.80	.00	.01	100.00	.10
+6	19.20	19.42	1.16	7.60	.00	.01	100.00	.10
+8	10.60	10.01	5.59	12.30	.00	.01	100.00	.10
+10	5.40	5.83	8.02	15.60	.00	.02	100.00	.10
+14	4.80	5.80	20.80	11.90	.70	1.64	134.39	115.60
+20	2.90	3.08	6.06	14.50	6.40	7.43	16.11	14.40
+28	1.10	.86	21.53	32.50	12.20	16.26	33.31	24.40
+35	.50	.23	53.46	63.70	14.00	12.37	11.67	7.90
+48	.00	.07	100.00	.10	17.30	17.42	.71	2.20
+65	.00	.03	100.00	.10	14.10	16.10	14.19	11.90
+100	.00	.01	100.00	.10	13.50	15.41	14.12	16.90
+150	.00	.01	100.00	.10	9.40	9.81	4.37	11.10
+150	.00	.18	100.00	.10	12.40	3.49	71.85	4.80

KILBORN

STREAMS	SEC O/S MEAS. VALUES	SEC O/S ESTIM. VALUES	SEC O/S RESID. VALUES	SEC O/S RELAT. ST.DEV.	PROD MEAS. VALUES	PROD ESTIM. VALUES	PROD RESID. VALUES	PROD RELAT. ST.DEV.
-742	2.20	2.19	.48	19.70	.00	.00	100.00	.10
-525	2.90	5.16	77.77	55.50	.00	.01	100.00	.10
-371	12.50	11.95	4.42	19.00	.00	.00	100.00	.10
-3	26.50	25.27	4.66	4.20	.00	.00	100.00	.10
-4	26.50	26.61	.41	4.50	.00	.00	100.00	.10
-6	23.90	23.42	2.01	9.70	5.50	6.38	16.07	25.90
-8	4.10	4.15	1.18	7.70	27.70	29.12	5.13	5.50
-10	.70	.70	.00	.10	22.50	22.58	.34	1.90
-14	.20	.20	.00	.10	26.50	24.06	9.21	9.20
-20	.50	.25	50.29	80.80	12.30	12.30	.01	3.50
-28	.00	.01	100.00	.10	3.60	3.64	1.04	5.50
-35	.00	.03	100.00	.10	.90	.91	.76	9.20
-48	.00	-.06	100.00	.10	.50	.49	1.70	16.30
-65	.00	-.03	100.00	.10	.20	.20	1.59	47.10
-100	.00	-.02	100.00	.10	.10	.10	.17	28.30
-150	.00	-.01	100.00	.10	.10	.10	.23	81.60
150	.00	.20	100.00	.10	.10	.11	5.28	28.30

MASS BALANCE RESULTS

TEST 2

ESTIMATES OF NETWORKS 1 & 2 VARIABLES

STREAMS	SOLID FLOW RATES MEAS. VALUES	ESTIM. VALUES	RESID. VALUES	RELAT. ST.DEV	PULP PERCENT SOLIDS MEAS. VALUES	ESTIM. VALUES	RESID. VALUES	RELAT. ST.DEV
NEW FEED	.00	29.51	100.00	.00	.00	.00	100.00	.00
COMPA1 IN	26.70	26.77	.28	2.67	.00	.00	100.00	.00
COMPB1 IN	35.60	35.48	.35	3.56	.00	.00	100.00	.00
SCREEN FEED	198.40	188.81	4.83	19.84	.00	.00	100.00	.00
PRIM O/S	.00	156.07	100.00	.00	.00	.00	100.00	.00
DUST	.00	32.74	100.00	.00	.00	.00	100.00	.00
SEC O/S	.00	126.56	100.00	.00	.00	.00	100.00	.00
PROD	.00	29.51	100.00	.00	.00	.00	100.00	.00
COMPA1 OUT	.00	26.77	100.00	.00	.00	.00	100.00	.00
COMPB1 OUT	.00	35.48	100.00	.00	.00	.00	100.00	.00

ESTIMATES OF NETWORK 3 MASS FRACTIONS

STREAMS	NEW FEED MEAS. VALUES	ESTIM. VALUES	RESID. VALUES	RELAT. ST.DEV.	COMPA1 IN MEAS. VALUES	ESTIM. VALUES	RESID. VALUES	RELAT. ST.DEV.
+742	.00	-.00	100.00	.10	.00	.00	100.00	.10
+525	.00	-.00	100.00	.10	.00	.00	100.00	.10
+371	.00	-.00	100.00	.10	.00	.00	100.00	.10
+3	.00	-.00	100.00	.10	.00	.00	100.00	.10
+4	.00	-.00	100.00	.10	.00	.00	100.00	.10
+6	.00	.00	100.00	.10	.00	.00	100.00	.10
+8	.00	-.00	100.00	.10	.00	.00	100.00	.10
+10	1.40	2.45	75.07	92.70	1.60	.88	45.08	86.70
+14	23.80	41.34	73.69	30.70	31.70	19.00	40.05	34.10
+20	26.60	39.91	50.04	21.70	26.00	19.99	23.13	22.80
+28	17.40	18.18	4.46	13.90	16.30	16.67	2.27	14.00
+35	13.40	2.31	82.74	14.60	9.20	9.48	3.00	3.40
+48	8.70	1.41	83.76	37.40	6.30	12.43	97.25	43.50
+65	3.10	-2.72	187.64	69.70	2.60	7.75	197.95	75.90
+100	1.80	-2.73	251.53	78.40	1.60	5.60	250.22	93.30
+150	1.90	-2.04	207.62	51.70	1.90	4.94	160.23	46.50
-150	1.90	1.90	.01	.10	2.80	3.24	15.71	1.40

STREAMS	COMPB1 IN MEAS. VALUES	COMPB1 IN ESTIM. VALUES	COMPB1 IN RESID. VALUES	COMPB1 IN RELAT. ST.DEV.	SCREEN FEED MEAS. VALUES	SCREEN FEED ESTIM. VALUES	SCREEN FEED RESID. VALUES	SCREEN FEED RELAT. ST.DEV.
+742	.00	.00	100.00	.10	.00	2.08	100.00	83.60
+525	.00	.00	100.00	.10	3.10	2.89	6.83	64.60
+371	.00	.00	100.00	.10	12.20	14.62	19.50	24.80
+3	.00	.00	100.00	.10	17.10	16.53	3.32	9.90
+4	.00	.00	100.00	.10	13.40	15.34	14.45	8.80
+6	.00	.00	100.00	.10	13.00	13.59	4.51	8.40
+8	.00	.01	100.00	.10	6.80	6.37	6.31	7.80
+10	1.90	1.40	26.51	52.90	4.40	4.01	8.96	9.30
+14	35.00	32.38	7.47	12.20	4.80	5.88	22.40	7.40
+20	30.50	24.64	19.23	16.60	4.20	3.38	19.50	13.40
+28	17.90	18.52	3.47	14.50	4.50	3.71	17.53	9.80
+35	7.50	7.60	1.36	2.20	3.60	2.53	29.92	16.70
+48	4.00	7.43	85.81	44.60	3.40	3.10	8.72	9.00
+65	1.10	2.95	168.21	93.50	2.50	2.16	13.59	10.20
+100	.60	1.71	184.47	101.50	2.10	1.58	24.74	13.10
+150	.60	1.48	145.86	68.60	1.70	1.38	18.96	7.40
-150	.90	1.86	107.07	17.60	3.10	.74	76.23	6.70

STREAMS	PRIM O/S MEAS. VALUES	PRIM O/S ESTIM. VALUES	PRIM O/S RESID. VALUES	PRIM O/S RELAT. ST.DEV.	DUST MEAS. VALUES	DUST ESTIM. VALUES	DUST RESID. VALUES	DUST RELAT. ST.DEV.
+742	3.80	2.63	30.87	83.10	.00	.01	100.00	.10
+525	3.40	3.49	2.70	12.30	.00	.01	100.00	.10
+371	15.10	17.68	2.32	24.30	.00	.01	100.00	.10
+3	20.80	20.00	3.86	10.50	.00	.01	100.00	.10
+4	18.00	18.55	3.06	7.80	.00	.01	100.00	.10
+6	16.10	16.43	2.07	7.60	.00	.01	100.00	.10
+8	7.90	7.71	2.47	12.30	.00	.01	100.00	.10
+10	4.20	4.84	15.27	15.60	.00	.02	100.00	.10
+14	4.50	4.30	4.37	11.90	10.80	13.37	23.80	115.60
+20	2.30	2.61	13.43	14.50	5.70	7.06	23.99	14.10
+28	.50	.86	71.43	32.50	8.60	17.32	101.38	24.40
+35	.10	.14	40.55	63.70	16.50	13.90	15.75	7.80
+48	.20	.20	.00	.10	16.80	16.95	.86	2.20
+65	.10	.10	.00	.10	10.90	11.98	9.92	11.90
+100	.00	.05	100.00	.10	9.40	8.89	5.41	16.90
+150	.00	.10	100.00	.10	7.40	7.49	1.15	11.10
+150	.00	.32	100.00	.10	13.90	2.96	78.73	4.80

KIEBORN

TEST 2

STREAMS	SEC O/S MEAS. VALUES	SEC O/S ESTIM. VALUES	SEC O/S RESID. VALUES	SEC O/S RELAT. ST.DEV.	PROD MEAS. VALUES	PROD ESTIM. VALUES	PROD RESID. VALUES	PROD RELAT. ST.DEV.
+742	3.10	3.24	4.47	19.70	.00	.00	100.00	.10
+525	5.30	4.31	18.77	55.50	.00	.00	100.00	.10
+371	20.10	21.80	8.47	19.00	.00	.00	100.00	.10
+3	24.10	24.66	2.32	4.20	.00	.01	100.00	.10
+4	23.90	22.88	4.28	4.50	.00	.00	100.00	.10
+6	18.80	18.02	4.14	9.70	8.10	9.62	18.80	25.90
+8	3.40	3.50	2.95	7.70	24.40	25.74	5.48	5.50
+10	.70	.70	.00	.10	22.50	22.60	.45	1.90
+14	.20	.20	.00	.10	25.00	21.90	12.40	8.20
+20	.10	.10	1.58	80.80	13.30	13.37	.56	3.50
+28	.30	.30	.00	.10	3.30	3.25	1.62	5.80
+35	.00	-.06	100.00	.10	1.00	.99	.65	8.20
+48	.00	.10	100.00	.10	.60	.63	4.38	16.30
+65	.00	.07	100.00	.10	.20	.22	9.26	47.10
+100	.00	.01	100.00	.10	.20	.20	1.04	28.30
+150	.00	.06	100.00	.10	.20	.25	24.29	81.60
-150	.00	.11	100.00	.10	.20	.21	4.80	29.30

MASS BALANCE RESULTS

TEST 3

ESTIMATES OF NETWORKS 1 & 2 VARIABLES

STREAMS	SOLID FLOW RATES MEAS. VALUES	ESTIM. VALUES	RESID. VALUES	RELAT. ST.DEV	PULP PERCENT SOLIDS MEAS. VALUES	ESTIM. VALUES	RESID. VALUES	RELAT. ST.DEV
NEW FEED	.00	29.67	100.00	.00	.00	.00	100.00	.00
COMPA1 IN	26.70	26.70	.01	2.67	.00	.00	100.00	.00
COMPB1 IN	35.60	35.61	.01	3.56	.00	.00	100.00	.00
SCREEN FEED	198.40	195.83	1.30	19.84	.00	.00	100.00	.00
PRIM O/S	.00	163.19	100.00	.00	.00	.00	100.00	.00
DUST	.00	32.64	100.00	.00	.00	.00	100.00	.00
SEC O/S	.00	133.52	100.00	.00	.00	.00	100.00	.00
PROD	.00	29.67	100.00	.00	.00	.00	100.00	.00
COMPA1 OUT	.00	26.70	100.00	.00	.00	.00	100.00	.00
COMPB1 OUT	.00	35.61	100.00	.00	.00	.00	100.00	.00

ESTIMATES OF NETWORK 3 MASS FRACTIONS

STREAMS	NEW FEED MEAS. VALUES	ESTIM. VALUES	RESID. VALUES	RELAT. ST.DEV.	COMPA1 IN MEAS. VALUES	ESTIM. VALUES	RESID. VALUES	RELAT. ST.DEV.
+742	.00	-.02	100.00	.10	.00	.01	100.00	.10
+525	.00	-.01	100.00	.10	.00	.00	100.00	.10
+371	.00	-.02	100.00	.10	.00	.01	100.00	.10
+3	.00	-.01	100.00	.10	.00	.01	100.00	.10
+4	.00	-.01	100.00	.10	.00	.01	100.00	.10
+6	.00	-.02	100.00	.10	.00	.01	100.00	.10
+8	.00	-.02	100.00	.10	.00	.01	100.00	.10
+10	6.20	8.34	34.58	5.00	5.80	4.08	29.71	5.00
+14	29.10	39.11	34.41	5.00	28.50	19.02	33.26	5.00
+20	21.20	22.42	5.75	5.00	20.00	18.61	6.94	5.00
+28	16.70	11.49	31.21	5.00	15.70	19.59	24.79	5.00
+35	9.70	7.11	26.66	5.00	9.60	11.79	22.76	5.00
+48	6.90	2.84	58.80	5.00	7.50	11.76	56.75	5.00
+65	3.60	3.02	16.19	5.00	3.50	3.98	13.81	5.00
+100	2.90	2.58	11.12	5.00	3.00	3.30	10.04	5.00
+150	2.30	1.98	14.11	5.00	3.40	4.03	18.42	5.00
-150	1.40	1.21	13.76	5.00	3.00	3.79	26.24	5.00

STREAMS	COMPB1 IN MEAS. VALUES	COMPB1 IN ESTIM. VALUES	COMPB1 IN RESID. VALUES	COMPB1 IN RELAT. ST.DEV.	SCREEN FEED MEAS. VALUES	SCREEN FEED ESTIM. VALUES	SCREEN FEED RESID. VALUES	SCREEN FEED RELAT. ST.DEV.
+742	.00	.05	100.00	.10	3.00	1.49	50.37	83.60
+525	.00	.04	100.00	.10	.20	.57	182.98	64.60
+371	.00	.05	100.00	.10	8.40	13.16	56.66	24.80
+3	.00	.05	100.00	.10	14.00	17.89	27.79	9.90
+4	.00	.05	100.00	.10	13.00	16.70	28.43	8.80
+6	.00	.05	100.00	.10	13.70	14.97	9.24	8.40
+8	.00	.05	100.00	.10	7.30	6.52	10.67	7.80
+10	9.40	4.22	55.12	5.00	5.50	3.84	30.20	9.30
+14	39.10	30.09	23.05	5.00	5.60	6.39	14.10	7.40
+20	22.40	24.93	11.28	5.00	5.10	5.76	13.03	13.40
+28	15.40	22.69	47.31	5.00	5.10	5.76	12.95	9.80
+35	7.30	9.50	30.13	5.00	4.50	2.44	45.76	16.70
+48	3.90	5.58	43.12	5.00	4.10	2.35	42.59	8.00
+65	.80	.84	4.98	5.00	3.00	.41	86.49	10.20
+100	.40	.41	2.17	5.00	2.20	.22	89.85	13.10
+150	.50	.52	4.10	5.00	2.00	.74	63.04	7.40
-150	.90	.88	10.10	5.00	3.30	.80	75.90	6.70

STREAMS	PRIM O/S MEAS. VALUES	PRIM O/S ESTIM. VALUES	PRIM O/S RESID. VALUES	PRIM O/S RELAT. ST.DEV.	DUST MEAS. VALUES	DUST ESTIM. VALUES	DUST RESID. VALUES	DUST RELAT. ST.DEV.
+742	.00	2.13	100.00	83.10	.00	.08	100.00	.10
+525	3.30	.67	79.74	12.30	.00	.05	100.00	.10
+371	12.60	15.78	25.20	24.30	.00	.08	100.00	.10
+3	22.80	21.45	5.90	10.50	.00	.08	100.00	.10
+4	19.00	20.02	5.37	7.80	.00	.08	100.00	.10
+6	16.80	17.94	6.81	7.60	.00	.08	100.00	.10
+8	8.80	7.81	11.26	12.30	.00	.08	100.00	.10
+10	6.20	4.54	26.84	15.60	.00	.35	100.00	.10
+14	5.90	5.10	13.51	11.90	.80	12.82	1503.08	115.60
+20	3.30	2.51	23.95	14.50	8.00	22.04	175.50	14.40
+28	.70	.85	20.79	32.50	15.90	30.34	90.79	24.40
+35	.20	.22	10.57	63.70	16.70	13.54	18.93	7.80
+48	.20	.20	.00	.10	16.40	13.12	19.98	2.20
+65	.20	.20	.00	.10	11.30	1.43	87.32	11.80
+100	.00	.11	100.00	.10	9.80	.80	91.80	16.90
+150	.00	.47	100.00	.10	7.60	2.07	72.81	11.10
-150	.00	.01	100.00	.10	13.50	2.96	78.06	4.80

STREAMS	SEC O/S MEAS. VALUES	SEC O/S ESTIM. VALUES	SEC O/S RESID. VALUES	SEC O/S RELAT. ST.DEV.	PROD MEAS. VALUES	PROD ESTIM. VALUES	PROD RESID. VALUES	PROD RELAT. ST.DEV.
+742	2.00	2.20	10.00	19.70	.00	.00	100.00	.10
+525	1.10	.82	25.60	55.50	.00	-.01	100.00	.10
+371	18.10	19.28	6.53	19.00	.00	-.00	100.00	.10
+3	26.30	26.22	.30	4.20	.00	-.00	100.00	.10
+4	26.10	24.47	6.24	4.50	.00	-.01	100.00	.10
+6	21.50	21.06	2.04	9.70	4.40	3.91	11.14	25.90
+8	3.70	3.98	7.58	7.70	24.30	25.04	3.03	5.50
+10	.70	.70	.00	.10	21.60	21.80	.92	1.90
+14	.20	.20	.00	.10	30.30	27.16	10.35	8.20
+20	.10	.12	19.45	80.80	13.20	13.27	.50	3.50
+28	.20	.20	.00	.10	3.80	3.75	1.30	5.80
+35	.00	.03	100.00	.10	1.10	1.10	[illegible]	8.20
+48	.00	.15	100.00	.10	.40	.41	[illegible]	16.30
+65	.00	.11	100.00	.10	.50	.61	22.[illegible]	47.10
+100	.00	.09	100.00	.10	.20	.2[illegible]	2.48	28.30
+150	.00	.02	100.00	.10	.00	2.5[illegible]	100.00	81.60
-150	.00	.36	100.00	.10	.20	.22	12.12	28.30

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Table B.2 - Simulated Compactor Impactor Circuit A Page 1

PCS Compaction Circuit Circuit A Tests	New Feed	Dust	Sec O/S	Compactor Impactor Feed	Compactor Feed	Impacted Sec O/S Calc	Impacted Flake	Screen Feed	Screen Feed Calc	Deviation
Test #1										
+0.742"	0.0%	0.0%	2.2%	1.3%	0.0%	0.2%	3.1%	1.3%	1.8%	-0.5%
+0.525"	0.0%	0.0%	5.2%	3.1%	0.0%	1.7%	5.4%	3.1%	3.3%	-0.1%
+0.371"	0.0%	0.0%	12.0%	7.3%	0.0%	7.0%	7.8%	7.3%	7.0%	0.3%
+3	0.0%	0.0%	25.3%	15.4%	0.0%	19.2%	9.4%	15.4%	14.1%	1.3%
+4	0.0%	0.0%	26.6%	16.2%	0.0%	23.5%	4.9%	16.2%	17.8%	-1.6%
+6	0.0%	0.0%	23.4%	14.3%	0.0%	23.0%	3.8%	15.5%	17.6%	-2.2%
+8	0.0%	0.0%	4.2%	2.5%	0.0%	6.5%	10.3%	8.0%	7.5%	0.4%
+10	0.6%	0.1%	0.7%	0.6%	0.3%	3.6%	6.3%	4.7%	5.3%	-0.7%
+14	23.6%	1.6%	0.2%	4.9%	12.2%	3.0%	8.0%	5.0%	4.6%	0.3%
+20	20.5%	7.4%	0.3%	5.5%	13.7%	2.7%	5.9%	4.0%	4.1%	-0.1%
+28	11.2%	16.3%	0.1%	5.5%	13.8%	2.2%	6.8%	4.0%	3.5%	0.5%
+35	5.0%	12.4%	0.0%	3.5%	8.9%	1.7%	4.3%	2.7%	2.9%	-0.2%
+48	14.0%	17.4%	0.0%	6.2%	15.8%	1.4%	7.1%	3.6%	2.5%	1.2%
+65	12.1%	16.1%	0.0%	5.6%	14.2%	1.1%	6.8%	3.3%	2.0%	1.3%
+100	8.2%	15.4%	0.0%	4.7%	11.9%	0.8%	6.8%	3.2%	0.9%	2.2%
+150	2.1%	9.8%	0.0%	2.4%	6.1%	0.6%	4.2%	2.0%	0.5%	1.5%
-150	2.6%	3.5%	0.0%	1.2%	3.1%	1.9%	-0.8%	0.9%	4.5%	-3.6%
Check	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%
Mass Balance Mg/hr	28.8	32.3	86.6	158.5	61.9	86.6	61.9	158.5	158.5	0.0

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28-Feb-89 Table B.2 - Simulated Compactor Impactor Circuit A Page 2

PCS Compaction Circuit Circuit A Tests	New Feed	Dust	Sec O/S	Compactor Impactor Feed	Compactor Feed	Impacted Sec O/S Calc	Impacted Flake	Screen Feed	Screen Feed Calc	Deviation
Test #2										
+0.742"	0.0%	0.0%	3.2%	2.2%	0.0%	0.4%	5.5%	2.1%	3.2%	-1.1%
+0.525"	0.0%	0.0%	4.3%	2.9%	0.0%	1.7%	5.4%	2.9%	4.4%	-1.5%
+0.371"	0.0%	0.0%	21.8%	14.6%	0.0%	13.8%	16.2%	14.6%	12.6%	2.0%
+3	0.0%	0.0%	24.7%	16.5%	0.0%	19.7%	10.1%	16.5%	15.9%	0.7%
+4	0.0%	0.0%	22.9%	15.3%	0.0%	21.2%	3.4%	15.3%	17.1%	-1.8%
+6	0.0%	0.0%	18.0%	12.1%	0.0%	18.7%	3.2%	13.6%	15.3%	-1.7%
+8	0.0%	0.0%	3.5%	2.3%	0.0%	6.1%	7.0%	6.4%	6.7%	-0.4%
+10	2.5%	0.1%	1.0%	1.1%	1.2%	3.8%	4.3%	4.0%	5.2%	-1.2%
+14	35.8%	13.4%	0.5%	8.2%	24.0%	3.2%	11.3%	5.9%	4.5%	1.4%
+20	39.9%	7.1%	0.1%	7.5%	22.6%	2.5%	5.3%	3.4%	3.6%	-0.3%
+28	18.2%	17.3%	0.0%	5.8%	17.7%	2.0%	7.2%	3.7%	3.0%	0.7%
+35	2.3%	13.9%	0.0%	2.8%	8.4%	1.6%	4.4%	2.5%	2.5%	0.0%
+48	1.4%	17.0%	0.0%	3.2%	9.6%	1.3%	6.8%	3.1%	2.1%	1.0%
+65	0.0%	12.0%	0.0%	2.1%	6.3%	1.0%	4.6%	2.2%	1.8%	0.4%
+100	0.0%	8.9%	0.0%	1.5%	4.7%	0.8%	3.2%	1.6%	0.1%	1.5%
+150	0.0%	7.5%	0.0%	1.3%	3.9%	0.6%	3.0%	1.4%	-0.1%	1.5%
-150	0.0%	3.0%	0.0%	0.5%	1.6%	1.7%	-0.9%	0.9%	2.0%	-1.2%
Check	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%
Mass Balance Mg/hr	28.5	32.7	126.6	188.8	62.3	126.6	62.3	188.8	188.8	0.0

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Table B.2 - Simulated Compactor Impactor Circuit A Page 3

PCS Compaction Circuit Circuit A Tests	New Feed	Dust	Sec O/S	Compactor Impactor Feed	Compactor Feed	Impacted Sec O/S Calc	Impacted Flake	Screen Feed	Screen Feed Calc	Deviation
Test #3										
+0.742	0.0%	0.0%	2.2%	1.5%	0.0%	0.3%	4.0%	1.5%	3.5%	-2.0%
+0.525"	0.0%	0.0%	0.8%	0.6%	0.0%	0.3%	1.1%	0.6%	3.5%	-2.9%
+0.371"	0.0%	0.0%	19.3%	13.1%	0.0%	12.4%	14.8%	13.2%	12.2%	1.0%
+3	0.0%	0.0%	26.2%	17.9%	0.0%	20.8%	11.6%	17.9%	17.2%	0.7%
+4	0.0%	0.0%	24.5%	16.7%	0.0%	22.2%	4.9%	16.7%	18.1%	-1.4%
+6	0.0%	0.0%	21.1%	14.4%	0.0%	21.0%	2.0%	15.0%	16.8%	-1.9%
+8	0.0%	0.0%	4.0%	2.7%	0.0%	6.0%	7.6%	6.5%	6.5%	-0.0%
+10	8.2%	0.9%	1.0%	2.1%	4.4%	3.5%	4.6%	3.8%	4.7%	-0.9%
+14	39.1%	12.8%	0.4%	8.3%	25.3%	2.7%	14.2%	8.4%	4.2%	2.2%
+20	22.4%	22.0%	0.2%	7.2%	22.2%	2.3%	13.2%	5.8%	3.5%	2.3%
+28	11.5%	30.3%	0.4%	7.0%	21.4%	2.1%	13.6%	5.8%	3.1%	2.7%
+35	7.1%	13.5%	0.0%	3.3%	10.5%	1.4%	4.6%	2.4%	2.3%	0.1%
+48	2.8%	13.1%	0.0%	2.6%	8.2%	1.2%	4.9%	2.4%	1.9%	0.4%
+65	3.0%	1.4%	0.0%	0.7%	2.2%	0.9%	-0.6%	0.4%	1.7%	-1.2%
+100	2.6%	0.8%	0.0%	0.5%	1.6%	0.7%	-0.8%	0.2%	-0.2%	0.4%
+150	2.0%	2.1%	0.0%	0.6%	2.0%	0.5%	1.2%	0.7%	-0.1%	0.8%
-150	1.2%	3.0%	0.0%	0.7%	2.1%	1.6%	-0.8%	0.8%	1.1%	-0.3%
Check	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%
Mass Balance Mg/hr	29.7	32.6	133.5	195.8	62.3	133.5	62.3	195.8	195.8	0.0

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PCS Compaction Circuit Circuit A Tests	New Feed	Dust	Sec O/S	Compactor Impactor Feed	Compactor Feed	Impacted Sec O/S Calc	Impacted Flake	Screen Feed	Screen Feed Calc	Deviation
Mean of Three Tests										
+0.742	0.0%	0.0%	2.5%	1.7%	0.0%	0.3%	4.2%	1.6%	2.8%	-1.2%
+0.528"	0.0%	0.0%	3.4%	2.2%	0.0%	1.2%	4.0%	2.2%	3.7%	-1.5%
+0.371"	0.0%	0.0%	17.7%	11.7%	0.0%	11.1%	12.9%	11.7%	10.6%	1.1%
+3	0.0%	0.0%	25.4%	16.8%	0.0%	19.9%	10.4%	16.8%	15.7%	0.9%
+4	0.0%	0.0%	24.7%	16.1%	0.0%	22.3%	4.4%	16.1%	17.7%	-1.6%
+6	0.0%	0.0%	20.8%	13.6%	0.0%	20.9%	3.0%	14.7%	16.6%	-1.9%
+8	0.0%	0.0%	3.9%	2.5%	0.0%	6.2%	8.3%	7.0%	6.9%	0.0%
+10	3.8%	0.4%	0.9%	1.2%	2.0%	3.6%	5.1%	4.2%	5.1%	-0.9%
+14	32.8%	9.3%	0.4%	7.1%	20.5%	3.0%	11.2%	5.7%	4.4%	1.3%
+20	27.6%	12.2%	0.2%	6.7%	19.5%	2.5%	8.1%	4.4%	3.7%	0.6%
+28	13.6%	21.3%	0.2%	6.1%	17.8%	2.1%	9.2%	4.5%	3.2%	1.3%
+35	4.8%	13.3%	0.0%	3.2%	9.2%	1.6%	4.4%	2.6%	2.6%	-0.0%
+48	6.1%	15.8%	0.0%	4.0%	11.2%	1.3%	6.2%	3.0%	2.2%	0.9%
+65	5.1%	9.8%	0.0%	2.8%	7.6%	1.0%	3.6%	2.0%	1.8%	0.1%
+100	3.6%	8.4%	0.0%	2.2%	6.1%	0.8%	3.1%	1.7%	0.3%	1.4%
+150	1.3%	6.5%	0.0%	1.4%	4.0%	0.6%	2.8%	1.4%	0.1%	1.3%
-150	1.3%	3.1%	0.0%	0.8%	2.2%	1.7%	-0.8%	0.8%	2.5%	-1.7%
Check	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%
Mass Balance Mg/hr	29.6	32.6	118.9	181.1	62.2	118.9	62.2	181.1	181.1	0.0

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Table B.2 - Simulated Compactor Impactor Circuit A Page 5

PCS Compaction Circuit Circuit A Tests	New Feed	Dust	Sec O/S	Compactor Impactor Feed	Compactor Feed	Impacted Sec O/S Calc	Impacted Flake	Screen Feed	Screen Feed Calc	Deviation
STD of Three Tests										
+0.742	0.0%	0.0%	0.5%	0.4%	0.0%	0.1%	1.0%	0.3%	0.7%	0.6%
+0.525"	0.0%	0.0%	1.9%	1.2%	0.0%	0.6%	2.0%	1.2%	0.5%	1.1%
+0.371"	0.0%	0.0%	4.2%	3.2%	0.0%	3.0%	3.7%	3.2%	2.6%	0.7%
+3	0.0%	0.0%	0.6%	1.0%	0.0%	0.7%	0.9%	1.0%	1.2%	0.3%
+4	0.0%	0.0%	1.5%	0.6%	0.0%	0.8%	0.7%	0.6%	0.4%	0.2%
+6	0.0%	0.0%	2.2%	1.1%	0.0%	1.7%	0.7%	0.8%	1.0%	0.2%
+8	0.0%	0.0%	0.3%	0.2%	0.0%	0.2%	1.4%	0.7%	0.4%	0.3%
+10	3.2%	0.4%	0.1%	0.6%	1.7%	0.2%	0.9%	0.3%	0.2%	0.2%
+14	6.6%	5.4%	0.0%	1.6%	5.9%	0.2%	2.5%	0.6%	0.2%	0.8%
+20	8.7%	7.0%	0.1%	0.9%	4.1%	0.2%	3.6%	1.0%	0.2%	1.2%
+28	3.2%	6.4%	0.2%	0.7%	3.1%	0.1%	3.1%	0.9%	0.2%	1.0%
+35	2.0%	0.7%	0.0%	0.3%	0.9%	0.1%	0.1%	0.1%	0.2%	0.1%
+48	5.6%	1.9%	0.0%	1.6%	3.3%	0.1%	1.0%	0.5%	0.2%	0.3%
+65	5.2%	6.2%	0.0%	2.0%	5.0%	0.1%	3.1%	1.2%	0.2%	1.0%
+100	3.4%	6.0%	0.0%	1.8%	4.3%	0.1%	3.1%	1.2%	0.5%	0.8%
+150	0.0%	3.2%	0.0%	0.7%	1.7%	0.0%	1.2%	0.5%	0.3%	0.3%
-150	1.1%	0.2%	0.0%	0.3%	0.6%	0.1%	0.0%	0.0%	1.4%	1.4%
Mass Balance Mg/hr	0.1	0.2	16.0	16.2	0.2	16.0	0.2	16.2	16.2	0.0

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APPENDIX C

Calculation of the Weibull Probability Distribution

The Weibull probability distribution in density form is given by:

$$g(t) = (t^{\beta-1}/\theta)\exp(-t^{\beta}/\theta) \quad \ldots\ldots\ldots\ldots\ldots\ldots (c.1)$$

where $\beta>0$ is a shape parameter and $\theta>0$ is a scaling parameter. It has recently been tabulated by Fowlkes in the form of quantile-quantile plots.

The Weibull probability function is closely related to the gamma function as the mean and variance of the Weibull probability function are given by:

$$\text{mean} = \theta^{1/\beta}\ \Gamma(1/\beta + 1) \quad \ldots\ldots\ldots\ldots\ldots\ldots (c.2)$$

$$\text{var} = \theta^{2/\beta}(\Gamma(2/\beta + 1) - (\Gamma(1/\beta + 1))^{2}) \quad \ldots (c.2)$$

The experimental observation that potash size distributions have straight-line segments on Weibull-logarithmic paper is equivalent to assuming the density distribution:

$$h(x,\beta,x_{b}) = (\beta/(\ln 10\ x))\ t^{\beta-1}\ \exp(-t^{\beta}) \quad \ldots\ldots (c.3)$$

where $t = \log (x/x_{b})$ and x_{b} is the size analysis representing the pan. log is the common logarithm of x the relative mesh size. The segmentation of the particle size

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distribution implies that there is a multiplicity of component populations of the form (c.3).

Analytically, this implies that the overall distribution is of the form:

$$h(x) = \sum_{i=1}^{N} a_i \; h(x, \beta, x_{bi}) \qquad \text{.....(c.4)}$$

The Cory tests indicate that there are two sub-distributions for the compactor flake distributions.

The basic identification problem is the determination of the effective values of the parameters a_i, i and x_{bi}. This involves the solution of a non linear programming problem consisting of the normal least squares minimization:

$$\min \sum (y_i - h(x_i))^2 \qquad \text{.....(c.5)}$$

subject to the integral equation constraint:

$$\int_{x_b}^{x_t} h(x)dx = 1 \qquad \text{.....(c.6)}$$

The above mathematical program is called a decomposition problem and requires a considerable amount of functional and numerical analysis in order to develop a robust procedure. However, an approximate solution can be obtained for the two distribution

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decomposition problem which appears to be applicable to all the particle size distributions in a potash compaction circuit.

In this case equation (c.6) is replaced by the approximate constraint:

$$a_1 \int_{x_b}^{\infty} h(x, \beta, x_{b1})dx + a_2 \int_{x_b}^{\infty} h(x, \beta\, x_{b2})dx = 1 \ldots . (c.7)$$

Since both integrals in constraint (c.7) evaluate to 1.0 the parameter a_2 can be eliminated from the least squares minimization shown as expression (c.5) removing the constraint condition (c.6).

Initial attempts to use the Powell algorithm with the BOTM procedure failed due to a convergence problem. The problem appears to be related to the extreme sensitivity to estimating errors in the weaker population(ie. the one having the smaller parameter a_1) to noise in the fractional particle size distribution.

This computational problem suggests that it would be better to work with the cumulative size distributions:

$$H(x) = \int_{x_b}^{x} h(x)dx \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (c.8)$$

The problem formulated so far will be somewhat familiar to the Geostatistician who has worked with log-normal bi-modal grade

populations that are encountered in certain gold and porphyry copper deposits.

The integral in equation (c.8) can be obtained in closed form as:

$$H(x) = \sum_{i=1}^{2} a_i \exp(-z_i) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

where $z_i = (\log(x/x_{0i})^{\beta_i}$

A non-linear least squares fitting procedure was developed using the Powell algorithm.

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